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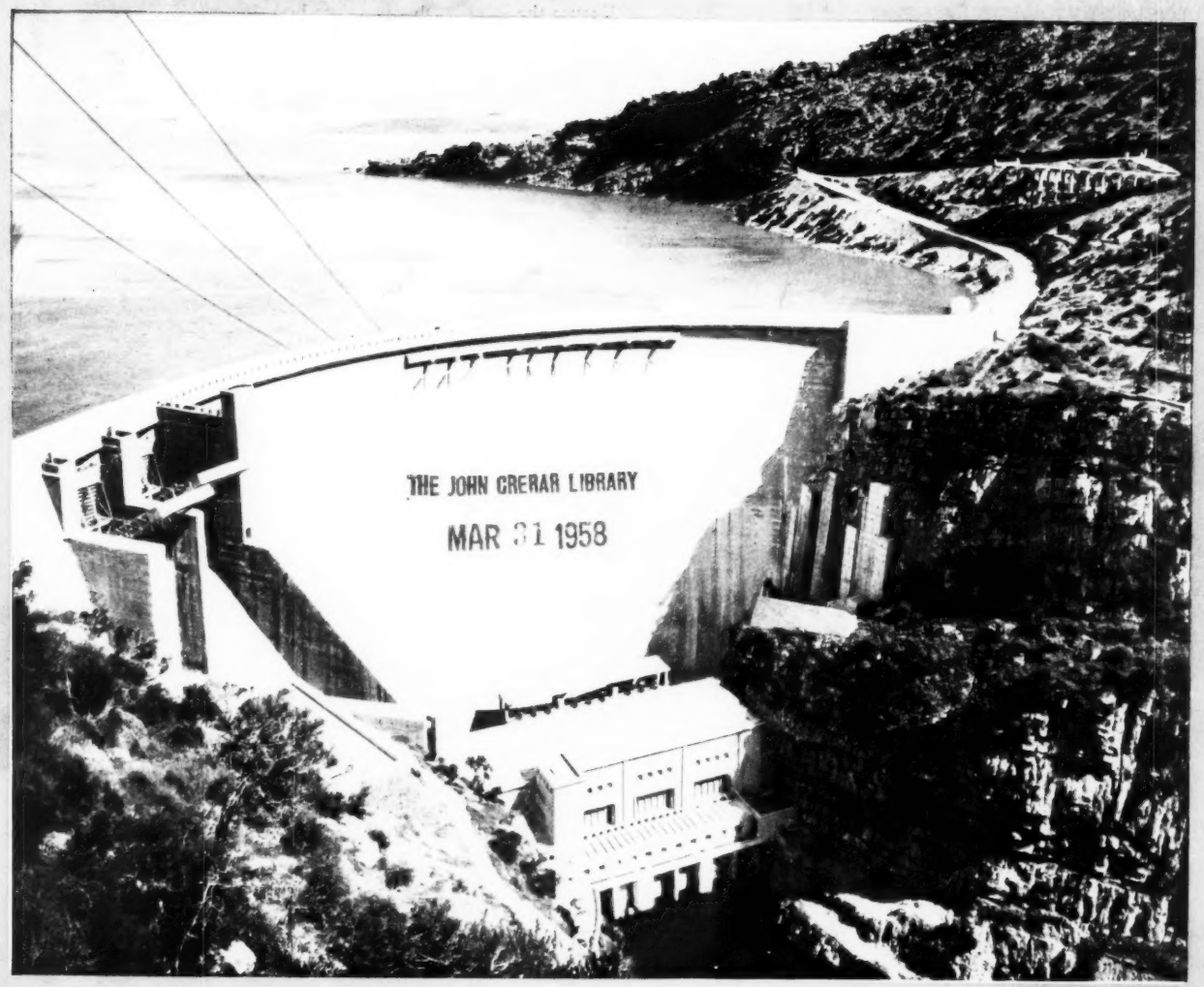
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

VOL. VII, NO. II NOVEMBER, 1957 RUPEES TWO



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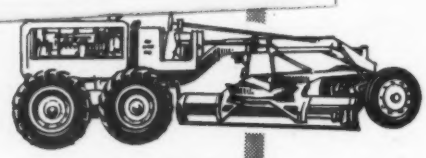
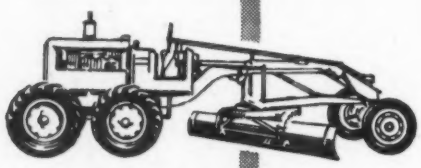
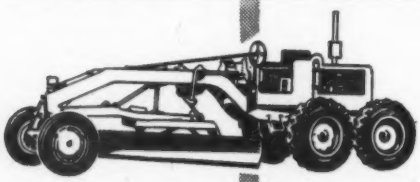


No. 12—115 HP



No. 112—75 HP



No. 212—50 HP

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CAT MOTOR GRADER SPECIFICATIONS

	No. 12	No. 112	No. 212
Engine	Diesel, four-stroke cycle		
Blade range :			
Lift above ground	16"	15½"	14½"
Side shift (right or left) ...	40"	36"	33¾"
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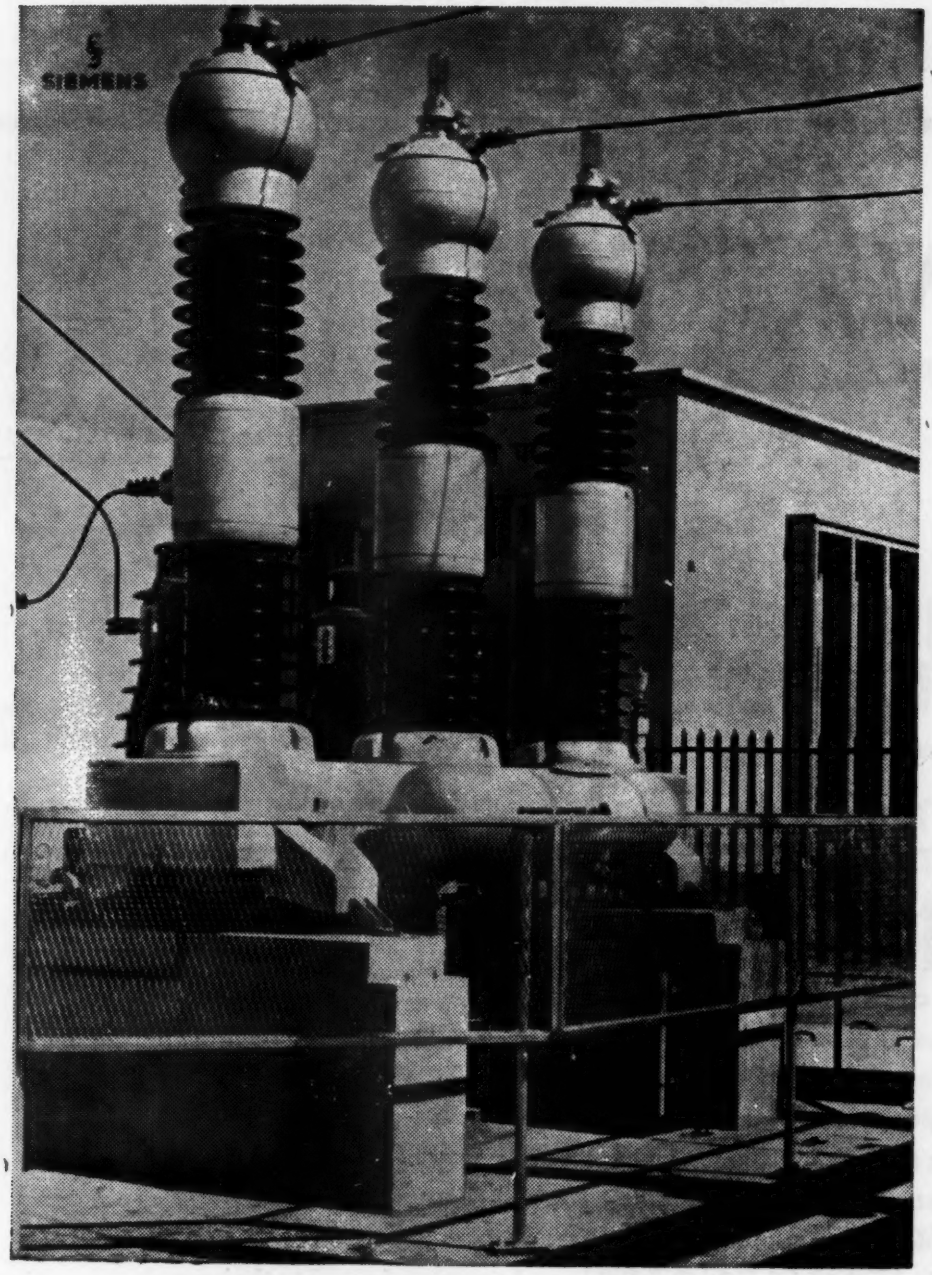

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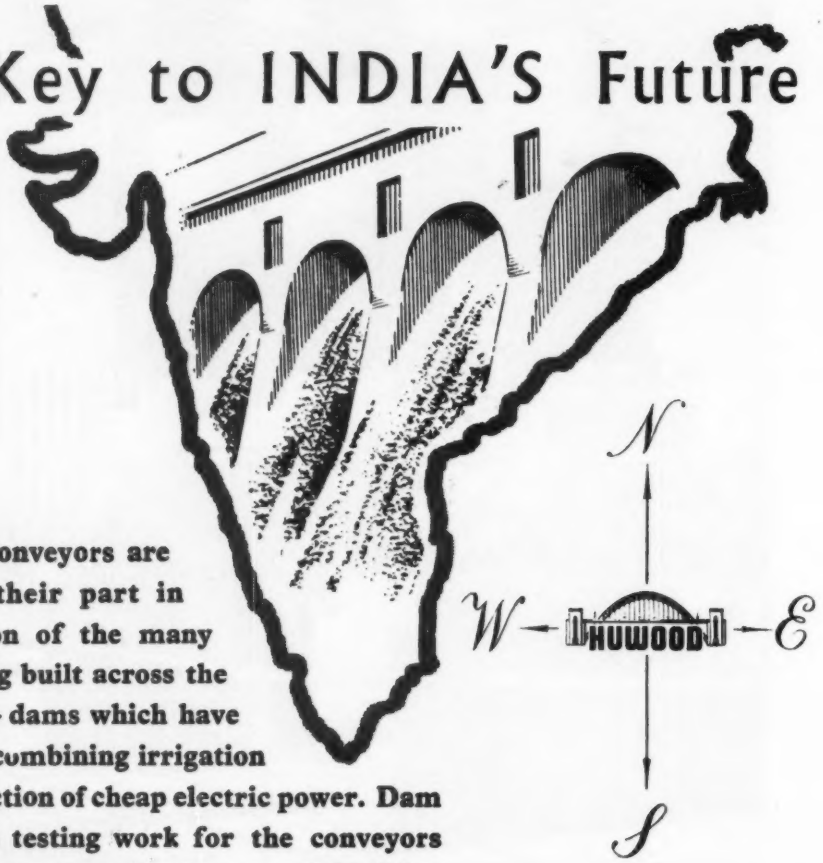

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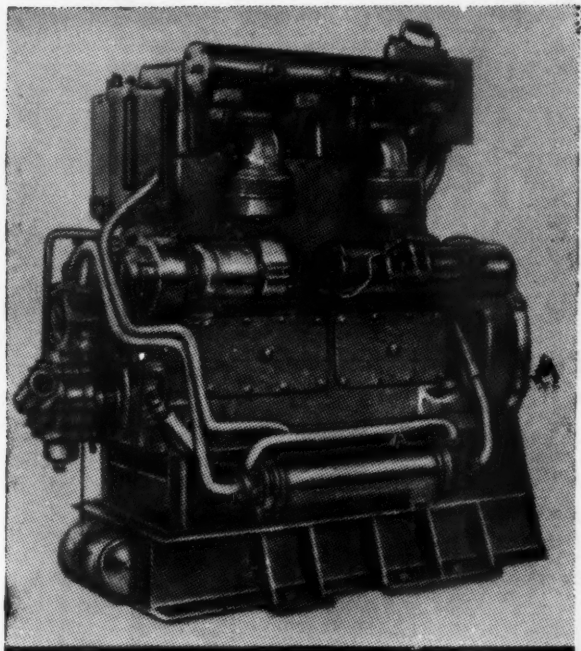

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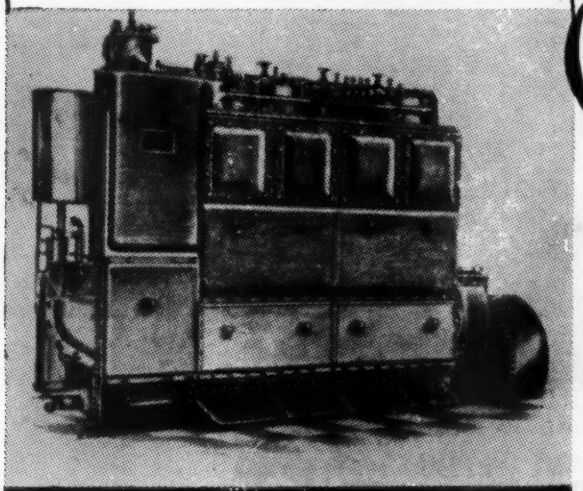

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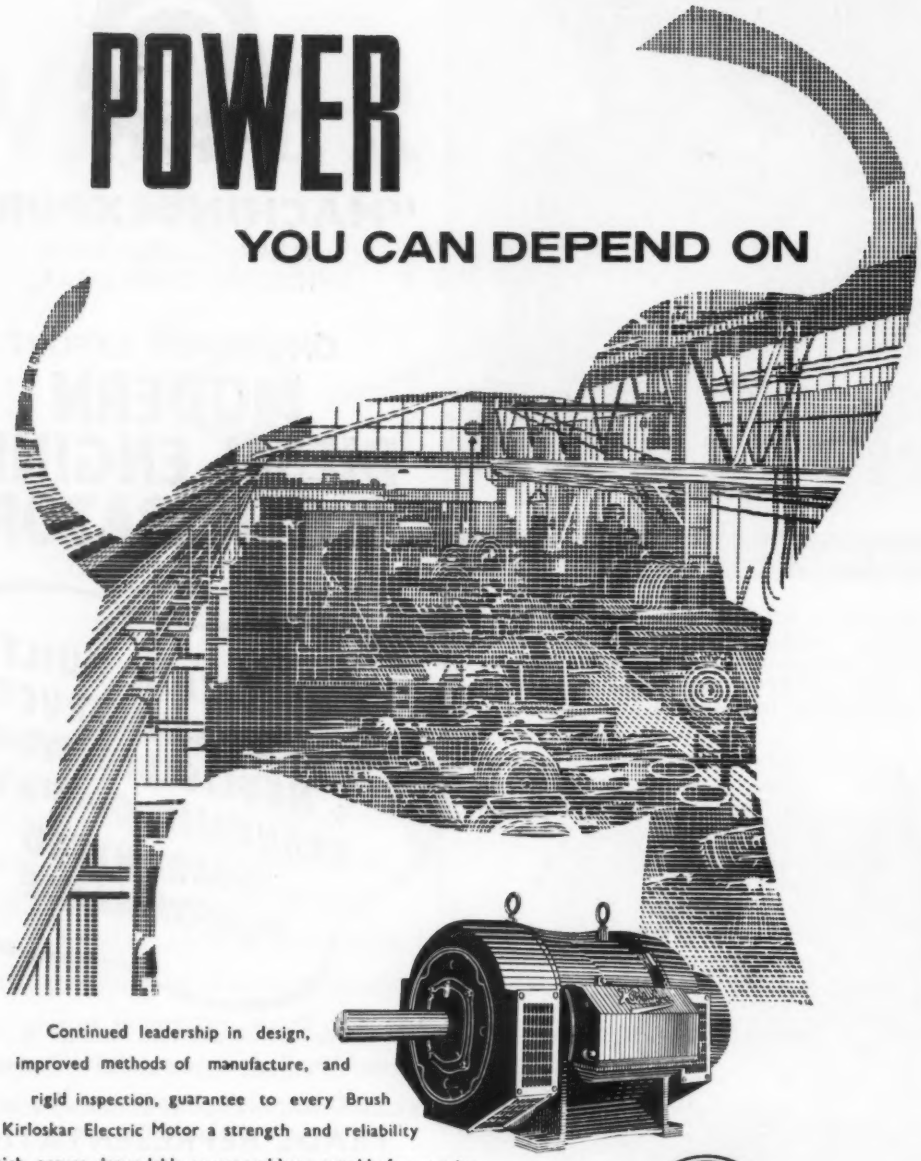

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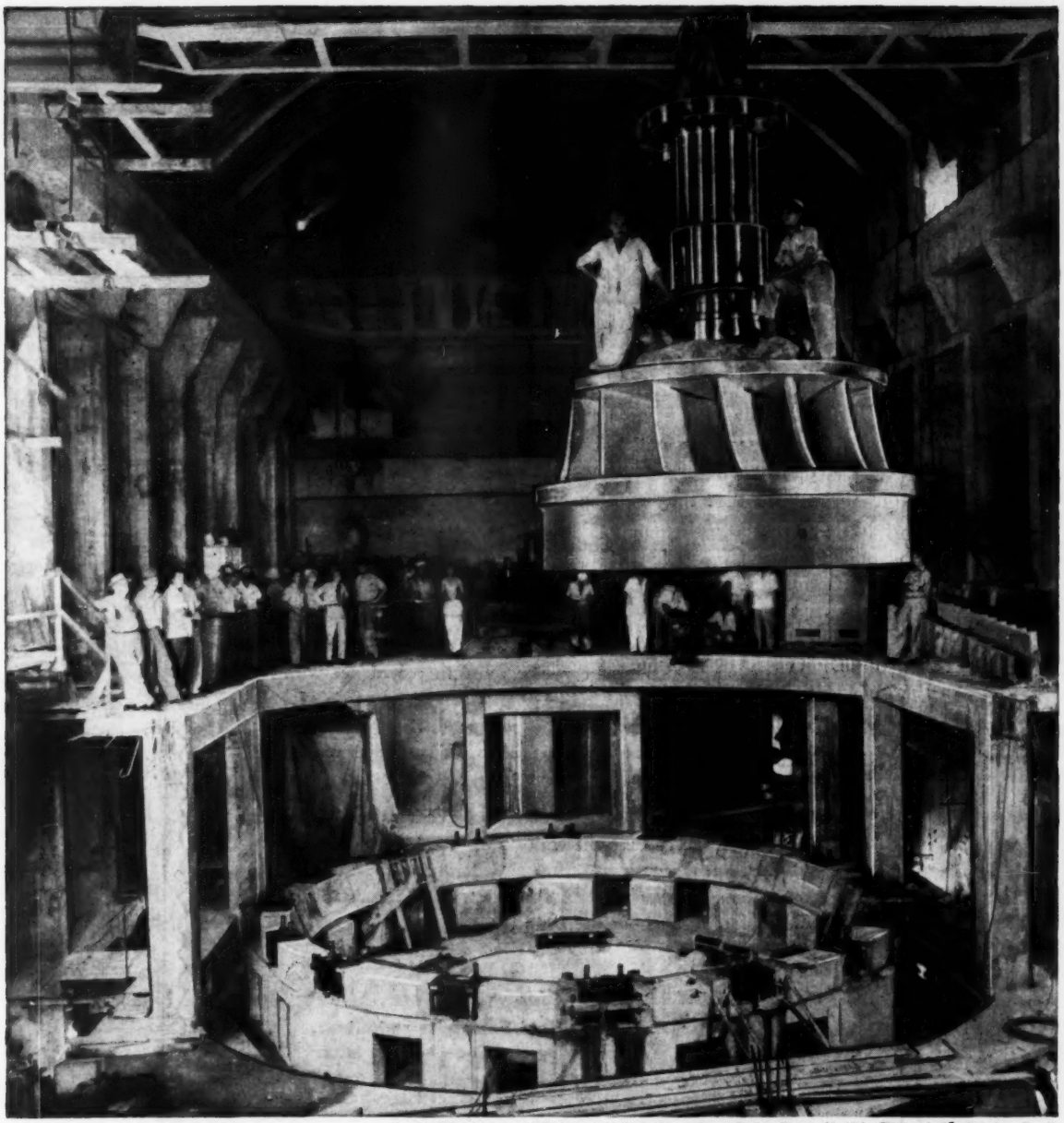

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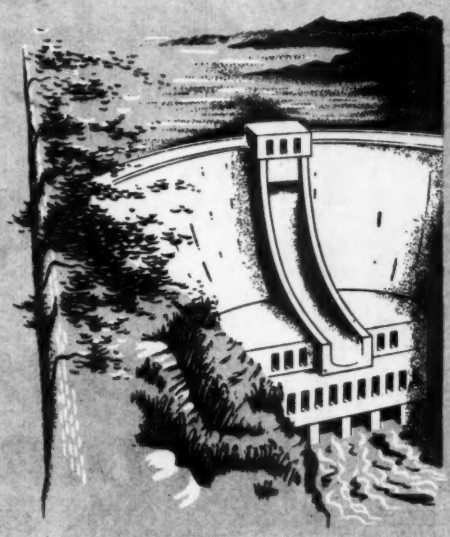

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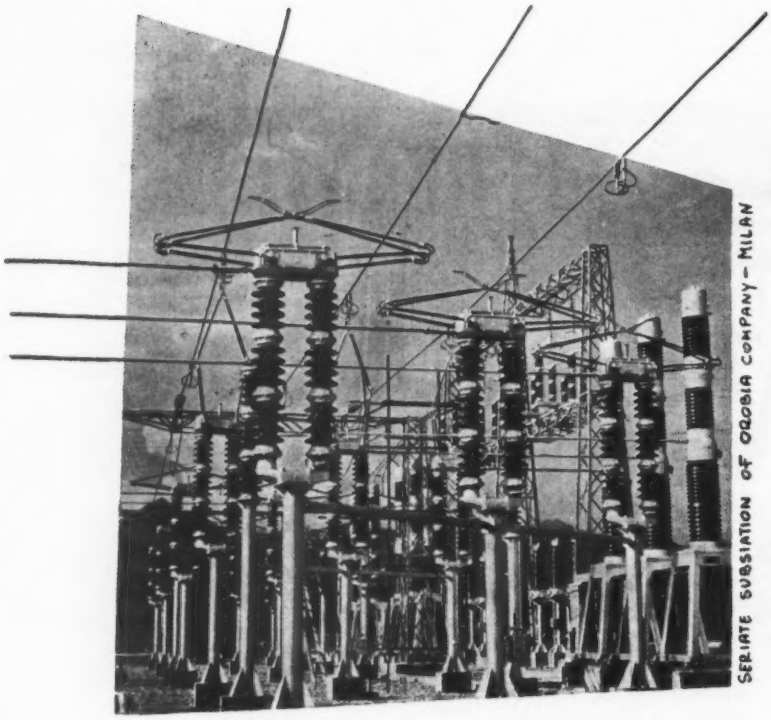

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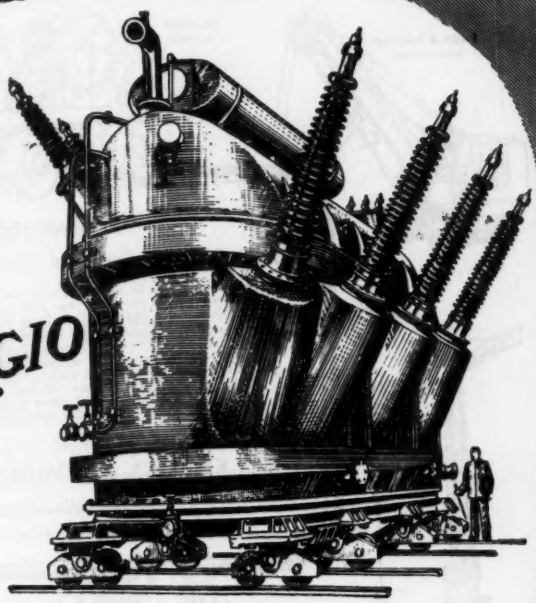

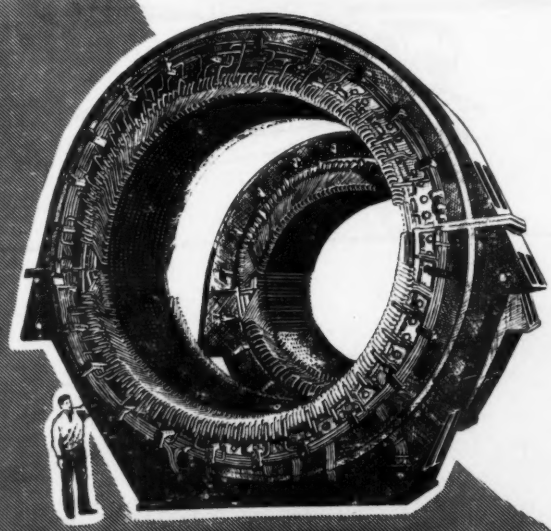

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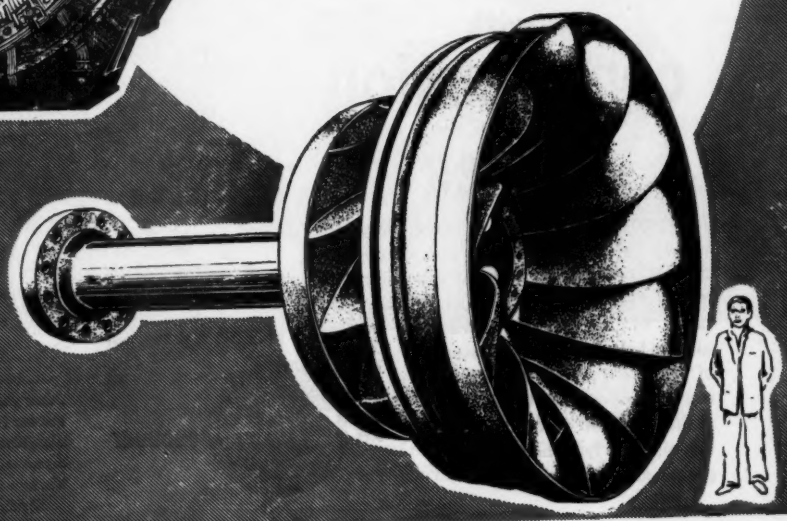

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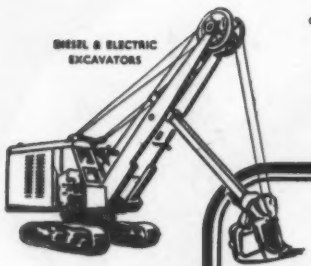

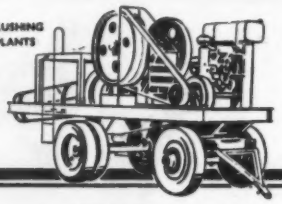

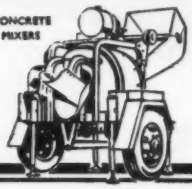

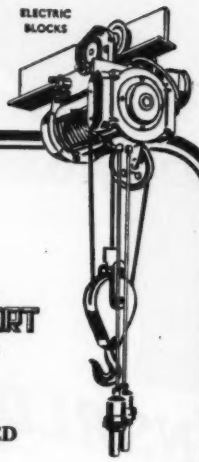

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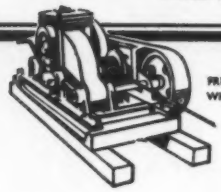

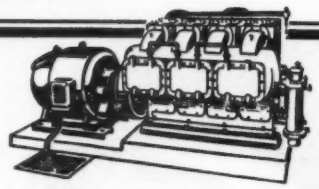

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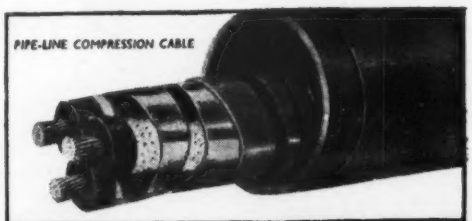

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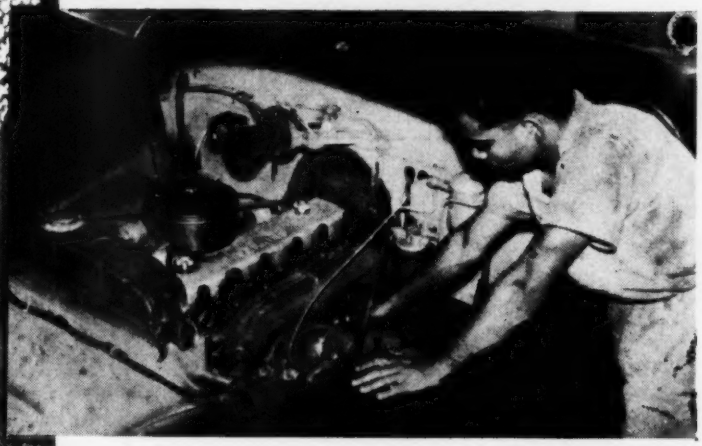

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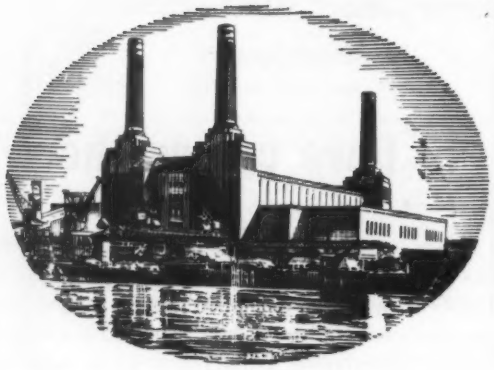

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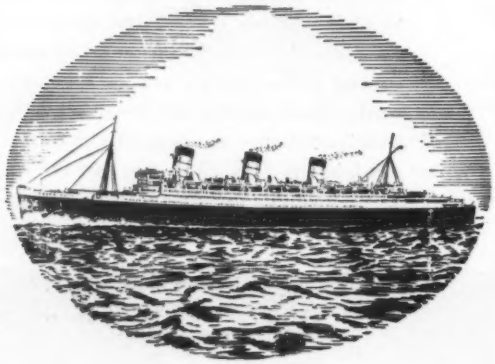

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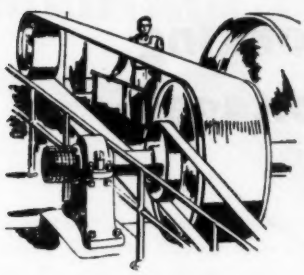

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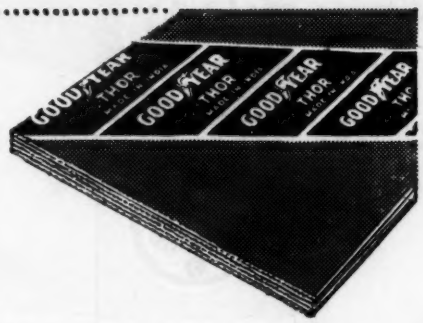

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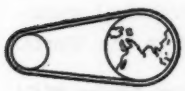

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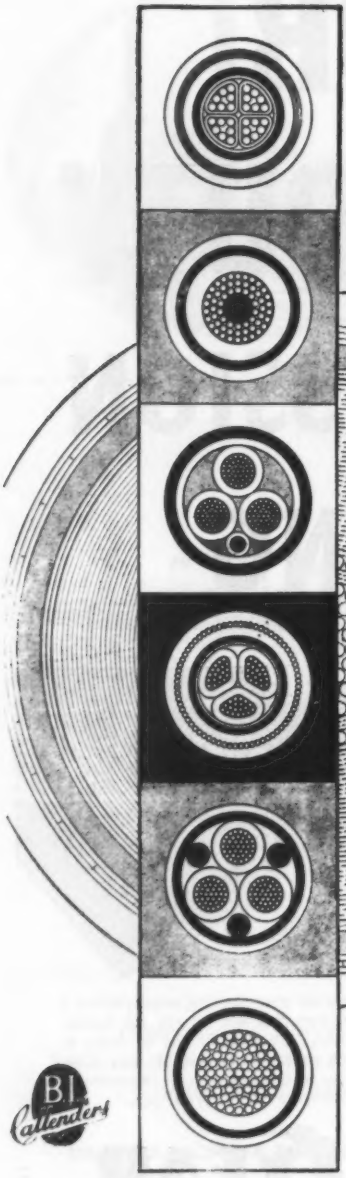

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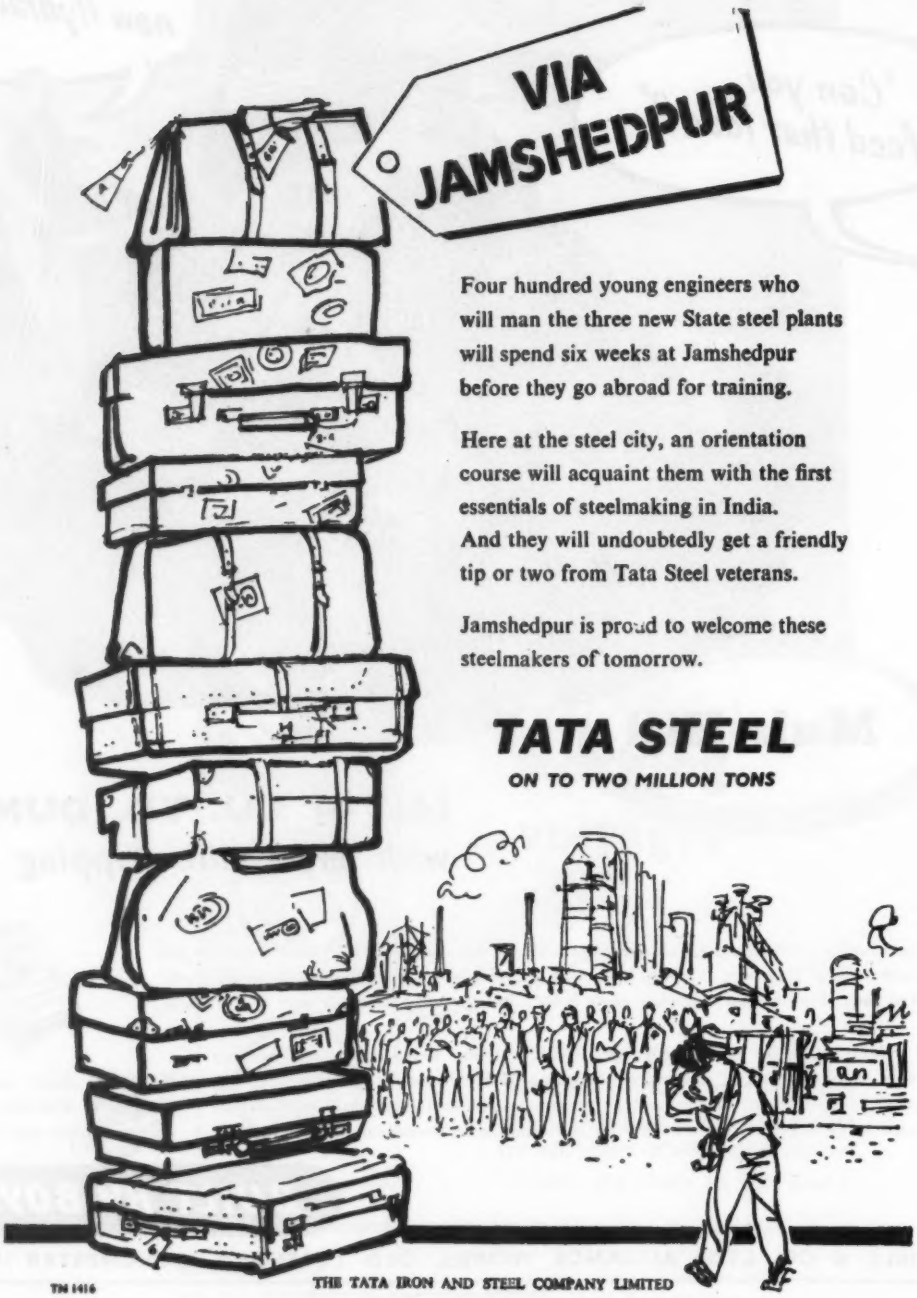

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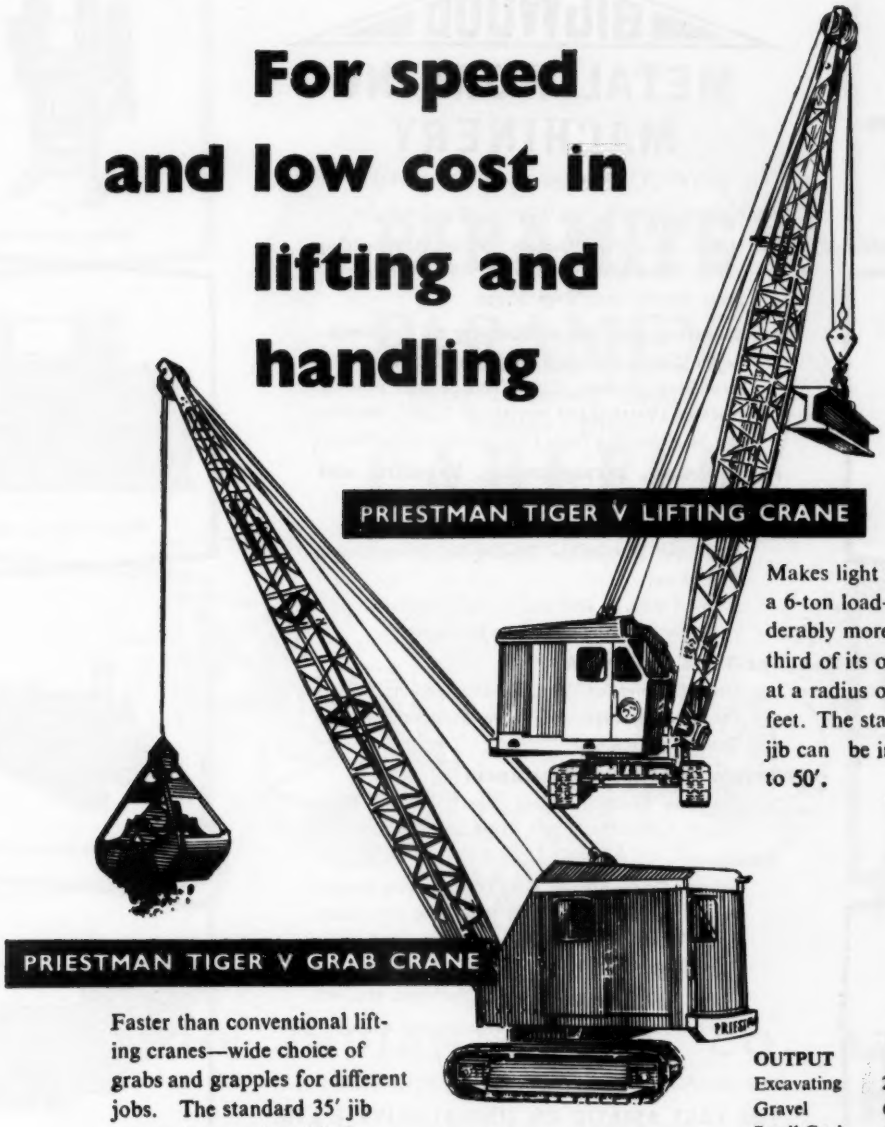

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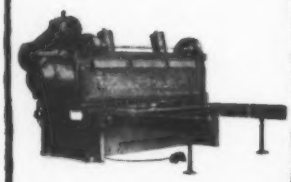
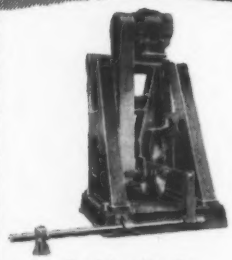


Precision Guillotine Plate Shears



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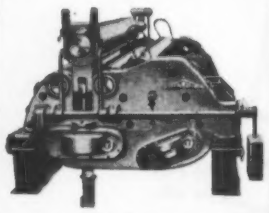

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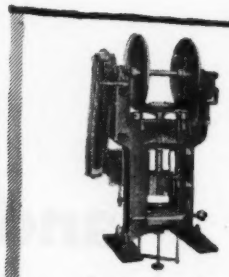
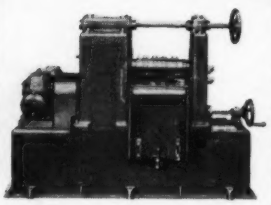
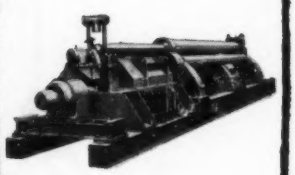


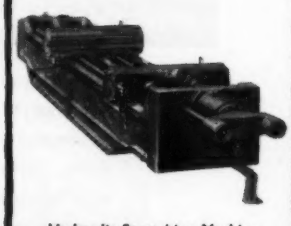
Friction Screw Press



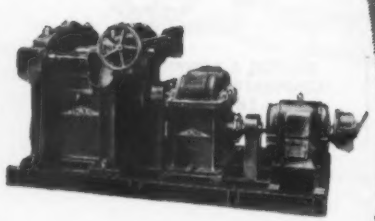
Gang Slitting Machine



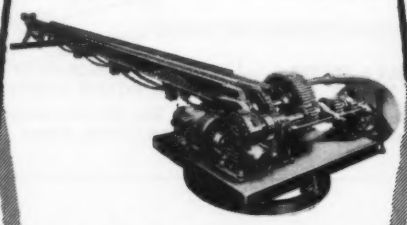
3-Roll Plate Bending Machine



Hydraulic Stretching Machine for Sheets



Bar Reeling Machine



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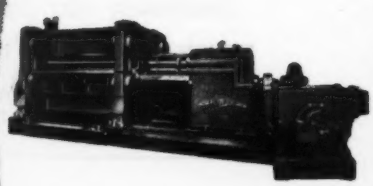

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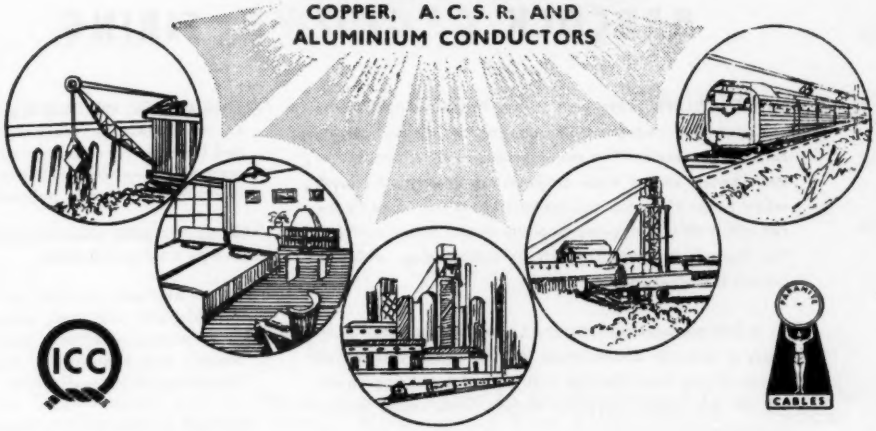

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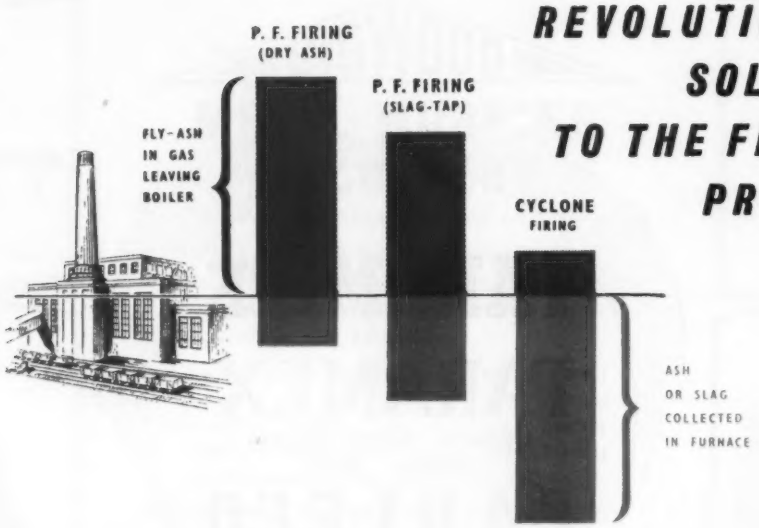

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OUTSTANDING advantage of the *Cyclone* furnace is the enormous reduction in quantity of fly-ash passing through the boiler. The major problems of ash collection and disposal and of stack emission are greatly simplified; while boiler efficiency and availability are increased by the reduction of slagging and deposits on the boiler surfaces. The *Cyclone* converts the ash to molten slag, which is quenched and easily disposed of.

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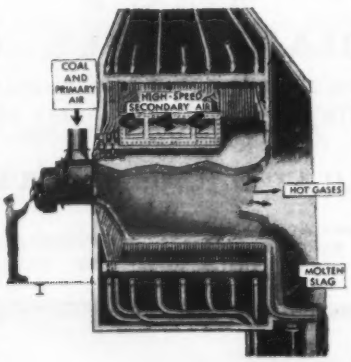

Highest boiler efficiency due to efficient combustion, cleaner boiler surfaces, and lower power consumption for coal preparation—since the coal need only be crushed or coarsely pulverized.

Burns even poor grade, high-ash coals, at high combustion rates.

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Vol. VII **NOVEMBER 1957** **No. 11**

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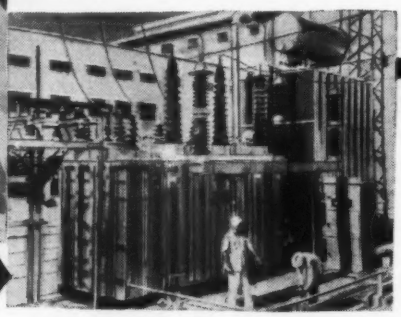
For the Hirakud Dam Project in Orissa two 37,500 KW, generating units are being supplied by the Company. Alongside is shown one of the generating units.



'English Electric 38,000 KVA Transformers installed at the Delhi Grid Sub-station distributing BHAKRA NANGAL POWER to Delhi.

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- Electric locomotives—including electrical equipment and mechanical parts
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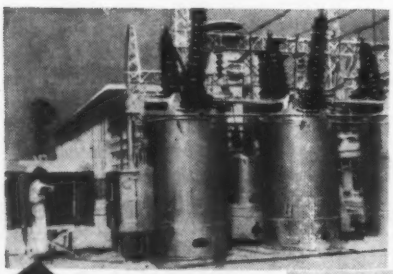
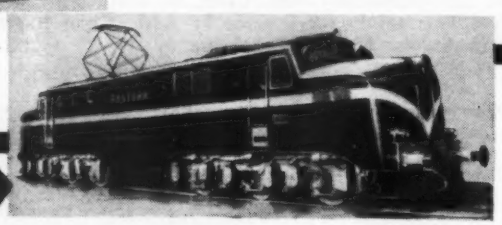
- Many thousands of horsepower of electrical drives for steel, jute and cotton mills etc
- Marconi radar, communication and broadcasting equipment



The Sarda Power House has an installed capacity of 41,400 KW and is the largest hydro-electric station in Uttar Pradesh. The English Electric Company supplied, erected and commissioned all the plant for this Power House. Above is shown one of six 'English Electric' 132 kV Oil Circuit Breakers installed at this site.



One of the twelve 3,120 H.P. electric locomotives built by 'English Electric' for the Eastern Railway, India.

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EEC-40

The Canada-India Reactor: Its Design and Operating Features

F. J. BLEACKLEY

The Canada-India Reactor—known as C.I.R.—is an experimental nuclear reactor now being constructed near Bombay as a joint Canada-India project under the Colombo Plan.

The reactor is designed to provide facilities for research work on peaceful applications of atomic energy. It will be used for the development of fuels and materials for use in nuclear power reactors and for the production of radio-active isotopes for industrial, medical and scientific applications.

Plutonium may be recovered as a byproduct from the spent fuel elements and will be used later as a fuel in a more advanced reactor for power production. A limited amount of uranium 233 will also be produced, by irradiating thorium metal in regions of pile where neutrons might otherwise be 'lost' in the reflector and shielding outside the areas of high flux. Uranium 233 is used as an enriching agent with natural uranium for fuel in other reactors.

The C.I.R. is a high flux (max. 6.5×10^{13} neutrons/sq. cm./sec.) slow neutron, heavy-water moderated and fresh-water cooled reactor using natural uranium as fuel and is designed to be operated at a maximum power level of 40 megawatts (thermal).

This paper describes, in general terms, the design and construction of the project; from the point of view of the civil, mechanical and electrical engineers engaged upon the task of interpreting the ideas of nuclear specialists in terms of conventional engineering materials and techniques suitable for employment in a relatively undevelopoed tropical country.

This paper was read at the Seventyfirst Annual General and Professional Meeting of the Institute of Canada in June, 1957, and published in the Engineering Journal from where it has been taken.

THE design of the "pile" or reactor proper is based on Atomic Energy of Canada Limited's NRX reactor which has been in operation at Chalk River for the past ten years. The design of the rest of the Project, however, including the buildings, enclosers, cooling systems, air-conditioning and exhaust air plants, electrical equipment and auxiliaries generally, has been developed to suit the special requirements of the site and to permit the entire plant to be erected and maintained by the particular type of skilled labour available in India.

Building — The design of the building housing the reactor was dictated by the condition that in no circumstances should radio-active gaseous products be liberated into the atmosphere in the event of malfunctioning of the reactor. The C.I.R. is located adjacent to an area containing about 3 million people and in the extremely unlikely event that the reactor should be out of control, even temporarily, there must be no possibility of gaseous fission products escaping.

The pile and the storage block, i.e., the units containing the fissionable material, are, therefore, housed in a pressure-tight steel shell to which access can be gained only through ventilated airlocks.

The large diameter of the cylindrical vessel required (120 ft. 0 in.), dictated the adoption of the hemispherical dome as the only reasonable method of forming a true pressure vessel.

Reactor

Whilst it is, of course, beyond the scope of this paper to deal with nuclear considerations *per se*, the nuclear considerations which govern the design of experimental reactors generally must be kept in mind as they form the background against which all the "conventional" engineering problems must be viewed.

An experimental reactor is primarily a source of neutrons. The heat generated during the chain reaction producing the neutrons and the reaction occurring when neutrons are captured, is a necessary evil to be disposed of as unobtrusively and as efficiently as possible and is of interest only as a measure of the power level at which the reactor is operating. In a so-called power reactor, on the other hand, the pile is a source of heat and neutrons are of interest only in so far as they effect the heat-producing capacity of the pile and the amount of shielding required. The reaction is

the same in both cases; it is merely the designers' points of view which are different.

The principal nuclear considerations governing the design of C.I.R., and all experimental reactors of this type, are as follows :

(a) Neutrons must be conserved and not wasted (i.e., not "captured").

(b) When certain materials enter an area of neutron flux radioactive isotopes are produced having varying intensities of radioactivity and varying "decay periods"

(c) Heat is produced in all reactions involving neutrons.

(d) Neutrons, gamma rays and other radiations associated with nuclear reactions are extremely harmful to organic tissue and every precaution must be taken to shield personal and sensitive materials from them.

(e) Nuclear reactions progress rapidly and silently so that the instruments used to detect faults, measure quantities and indicate the state of a given process, and the equipment provided to act upon the signals given by those instruments must all respond with equal rapidity and must be automatic and reliable to a degree not required of equivalent apparatus used in other branches of engineering.

In the C.I.R. the nuclear reaction takes place inside a cylindrical aluminium tank called the calandria. This tank is 8 ft. 9 in. diameter and approximately 10 ft. 6 in. high. It consists of a thin shell attached to end tube-sheets each about three inches thick. Into the tube sheets are expanded light vertical tubes through which the fuel rods, shutoff rods and experimental (loop) rods are inserted.

The calandria contains the heavy-water which acts as a 'moderator', slowing down the fast neutrons emitted by the U235 until they have only the so-called 'thermal energy' necessary to maintain the chain reaction. The fast neutrons are slowed down from speeds of 10,000 miles per second to one mile per second.

The power-level at which the reactor is operating at any time is controlled by varying the level of the heavy-water in the calandria. Shutting down the reactor is accomplished by "dumping" part of the heavy-water into prepared tanks below the pile and at the same time inserting into the pile what are called 'shut-off' rods containing boron (which absorbs neutrons).

On C.I.R. provision has ben made for 186 fuel rods with six additional positions into which either fuel rods or 'loop' experiments may be placed.

A fuel 'rod' consists of a long aluminium tube having a central portion, approximately the same length as the calandria, containing a cylindrical core of uranium 1.36 in. diameter. The uranium is protected from the cooling water by a thin cladding of aluminium which is drawn down over the uranium core. An outer sheath of aluminium, separated from the core by a space 0.070 in. wide, forms an annular passage for the cooling water. The central "working" portion of the rod is attached to top and bottom sections which serves to conduct cooling water to and from the uranium section and provide shielding to the ends of the uranium core. The total length of the fuel rod is approximately 30 ft. 0 in. and the rod is handled in this length by a suspension device at its upper end.

Fuel rods are suspended in the pile from seatings formed at their upper ends which bear on bevelled shoulders in holes in a master plate at the top of the pile. The inlet ends of the rods seat against prepared sealing faces in a header assembly above the master plate. The bottom of the rods seal against similar faces on another header assembly below the pile and water is circulated through the fuel rods from the upper header to the lower header.

Having in mind a picture of the central core of the reactor in which the principal reaction takes place, attention can again be focused on considerations (a) to (e) above in so far as they affect the design of C.I.R.

(a) Neutrons which would otherwise escape from the sides of the calandria are returned to the core by a reflector. The reflector consists of two concentric hollow cylinders of graphite having an inner ring 9 in. thick, separated from the wall of the calandria by an annular clearance of 1½ in., and an outer ring 24½ in. thick separated in turn from the inner ring by an annular gap of 2½ in. Both rings of graphite are approximately 11 ft. 4 in. high.

In the 2½ in. annular gap provision is made for the suspension of up to 92 thorium rods to be irradiated by neutrons which have penetrated the inner, thinner, ring of graphite.

(b) The materials in the pile core must not absorb neutrons to any great extent and whilst aluminium and carbon do not have high 'capture cross sections' the impurities normally associated with these materials do have high cross-sections and besides absorbing neutrons they become highly radioactive in the process. For this reason special reactor grades of aluminium and graphite are used but their compositions are regarded as industrial secrets by the manufacturers.

Similarly, the cooling water and the heavy-water circulated through the pile must not contain impurities which will capture neutrons and thus become radioactive. The water in the cooling system is therefore treated before being charged into the system and continuously thereafter whilst the pile is operating.

The space above the heavy water in the calandria varies during operation and is kept filled with an atmosphere of helium which is not affected

by radiation and does not combine with heavy water. Air is not permitted to come into contact with heavy water as it would be carried into the pile and be irradiated. Air would also downgrade the heavy-water by the contaminating action of the nitrogen compounds formed during the irradiation so that a helium atmosphere must be provided over the heavy water at all times.

(c) Of the 40 megawatts total heat output of the pile approximately 38 megawatts are produced in the fuel elements themselves. The maximum temperature of the uranium at the centre of a rod is approximately 977 deg. F., and the maximum temperature of the inner sheath is 239 deg. F. The cooling water enters the upper header at a maximum temperature of 125 deg. F. and leaves the lower header at approximately 175 deg. F.

The minimum temperature of the fresh water coolant, which circulates in a closed circuit through heat exchangers, is set by the temperature of the sea-water used on the secondary side of the system. The sea reaches a temperature of 90 deg. F. in the hot season and the minimum temperature to which the primary cooling circuit can be cooled under these conditions is assumed to be 117 deg. F.

Primary cooling water is circulated at a maximum rate of 25 Imp. gallons per minute per rod, making a possible total of 5000 I.g.p.m. for the whole pile under full load conditions. The maximum pressure at the upper header is approximately 220 lb./ sq. inch. The pressure drop through the rod corresponding to a flow of 25 gallons per minute is 135 lb./ sq. inch.

The pressure at the lower header is 37 lb. per sq. inch, the balance being the pressure-drop across an orifice placed between the bottom of the fuel-rod and the lower header for the purpose of calibrating and measuring the flow of water during operation.

The reaction within the calandria produces heat in the heavy water and so further heat exchangers are provided to dissipate a total of 2000 kW. of heat from the heavy water.

Heat is also generated when neutrons and other radiations are stopped by the shielding materials provided for the protection of personnel, as outlined below under (d).

As the calandria tube-sheets are 3 in. thick it is not considered necessary or practicable to instal reflectors above and below the calandria, as neutrons would have to pass through the 3 in. aluminum plate twice and most of them would be captured in the process.

To absorb neutrons and other radiations escaping through the ends of the calandria, devices called thermal shields are provided above and below the pile cord.

Immediately below the calandria is a shallow aluminum vessel consisting of a short shell and two heavy tube-sheets drilled for and provided with tubes through which the lower ends of the fuel rods pass. The vessel is called a removable thermal shield and rests in the centre of a fixed steel vessel of similar construction but of doughnut shape.

The inner aluminum section and the outer steel section of the shield are filled with water and the assembly forms a sandwich in which the water slows down the fast neutrons and the metal captures the resulting thermal neutrons and other escaping radiations.

Below the first section of the lower thermal shield are two more fixed shields of sandwich construction made from heavy steel plates. The object of using aluminum for one section is that if it should ever be required to remove it to gain access to the steel shield below, the high purity metal would not contain radio active impurities having so long a decay period that handling the shield would be out of the question.

Above the calandria is a similar steel 'doughnut' fitted with a removable aluminum centre section and above this are steel 'doughnuts' having removable steel centre sections. All three of these water-cooled shields are fitted with tubes through which the fuel rods and other facilities can be inserted.

Two separate water cooling systems are used on the thermal shields, one for the steel shields and one for the aluminum shields. This is done to provide cooling-water having the correct anti-corrosion characteristics appropriate to the metals in the systems. Each system is further divided to the fixed and removable sections.

From the two aluminum shields a total of approximately 100 kW. of heat is removed and from the steel shields approximately 130 kW. This heat also is dissipated in heat exchangers using sea water at 90 deg. F. on the secondary side, thus the minimum temperature of the cooling water entering the aluminum shields is approximately 100 deg. F.

Water cooled shields are not provided at the sides of the pile to stop radiations which escape from the reflector graphite. Instead, two concentric rings of cast-iron, each 6 in. thick are provided, separated from each other by an annular gap of 2 in. and from the outer ring of graphite by an annular gap of 2 in. The cast-iron shields, the graphite and the J-rods are cooled by a stream of air which emerges from a circular duct below the cast-iron shields and passes upwards, through the annular spaces between the cast-iron ring and between the outer ring and the concrete construction, and then passes down between the concentric rings of graphite, over the J-rods and into a second duct concentric with the inlet duct and thence out to the exhaust air fans and the stack.

Openings are provided in the cast-iron thermal shields to accommodate the thermal columns, to be described later, but the annular air passages are maintained to facilitate the flow of cooling air over the cast-iron and graphite surfaces.

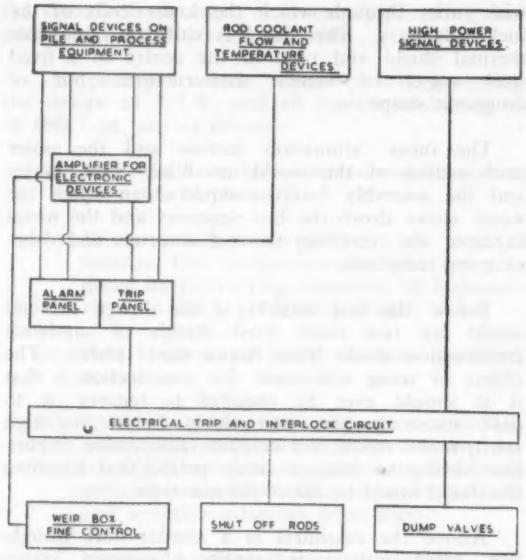


Fig. 1—Schematic arrangement of automatic safety control system

(d) Whilst the water-cooled and cast-iron thermal shields effectively contain most of the neutrons within the pile, gamma rays and other radiations associated with the neutron capture in the thermal shields, are radiated from the sides of the shields. Further protection must be provided therefore to reduce the intensity and strength of the escaping radiations below what is called the biological tolerance.

The additional shielding is called biological shielding ; it is made of concrete which contains sufficient hydrogen to slow down any fast neutrons and sufficient heavy material to capture slow neutrons and absorb secondary radiations.

The biological shield around the side of the pile consists of a wall of concrete 8 ft. thick, poured in position at the time of construction. Above the thermal shields, four steel trays are provided, each 12 in. deep, filled with reinforced concrete and fitted with vertical tubes through which the fuel and other rods can be inserted. These shields are supported on cast-iron webs embedded in the structural concrete and may be removed to gain access to the pile core.

To prevent neutrons from streaming out of the pile along the sides of fuel rods and other openings in the shielding, all holes are stepped and the rods, plugs and other inserts are similarly stepped so that there are, at all times, no direct paths along which neutrons may escape.

Below the lower thermal shields it is not considered necessary, or practicable, to provide biological shielding as the area is not accessible whilst the pile is in operation.

To guard against the effects of possible radiations escaping from the tops of the shut-off rods and from fuel rods being removed from the pile, a final shield is provided in the form of a hollow floor at the top of the pile. The floor consists of a steel and water sandwich, similar in construction to the steel shields except that the water is not circulated because very little heat is generated.

The floor is circular and contains a concentric revolving centre section which, in turn, has a further revolving section within it but eccentric to the axis of the main turntable. The small inner turntable contains a hole over which the rod handling flask can be centred. By revolving the two turntables through predetermined angles the hole may be located over any rod position in the reactor.

(e) When the reactor is operating at full power a great deal of heat is generated in the components, as has been described, and adequate cooling capacity must be available at all times. If the reactor should be allowed to start with inadequate cooling available, or if it should be allowed to exceed the rated power with only normal cooling capacity present, then serious damage could result.

To prevent the reactor from starting if an unsafe condition exists and to shut it down if an unsafe condition develops during operation, the reactor and its auxiliaries are provided with an automatic safety control system. The system is shown diagrammatically in Fig. 1.

The two principal devices in the automatic safety control systems are :

(i) Shut-off rods,

(ii) Dump valves.

The shut-off rods are considered the primary protective devices and are designed to "trip" or shut the reactor down quickly. The dump valves permit the heavy-water in the calandria to fall rapidly from the maximum level of 307 cm. to the 150 cm. level, giving supplementary shut down at a moderate rate.

The automatic safety control system is a very involved one, designed to fulfil the requirements that the reactor be started-up, operated and shut-down safely. Information from various signal devices is fed into an electrical trip and inter-lock circuit which interprets the information and actuates the principal control devices.

The automatic safety control system is also designed so that operational mistakes will not contribute to disastrous consequences.

To protect the reactor from the effects of faulty instruments and defective circuits, signals are divided into two types, trip signals and alarm signals. Generally, three signal devices are provided to indicate a particular type of fault or condition; a signal by one device alone will actuate an alarm signal which may be a visual or an aural device, but a signal from two out of

the three instruments will actuate a trip and an alarm signal.

Trips are further subdivided into two types — conditional trips and absolute trips :

Certain trip signals are 'conditioned' by low-power measuring devices as follows :

(i) The trip signals result in a shut-off rod release and heavy-water dump if the power is above one per cent of full power, e.g., when the pile is shut down and some of the shut-off rods are raised.

The principal reason for operating at less than 1 per cent power is to keep the reactor from "poisoning out" while troubles are being corrected.

Absolute trips result in the release of all the shut-off rods and the dumping of heavy-water in both the low and high power stages. Absolute trips prevent shut-off rods from being raised or the heavy-water dump valves being closed if the equipment is not in good working condition. Absolute trips also prevent shut-off rods from being raised when the pile is at low power stage with heavy-water in the calandria if the shut-off rod mechanisms are in any way faulty and cannot be re-lowered.

All signals actuated by high-power devices give rise to absolute trips even if the signal results from faulty equipment (conditioned, of course, by the 2 out of 3 coincidence system) as it would be hazardous to operate or even to start the pile with high power devices unserviceable.

All the safety control devices are designed to "fail-safe" so that, as far as possible, failure of the equipment will not prevent the control device from operating. For example, the calandria dump-valves are held closed by compressed air and are opened on the release of the compressed air by powerful springs, so that in the event of an air failure the valves would automatically open and the pile would shut down. The shut-off rods are similarly designed so that they are raised mechanically, but lowered automatically by the action of gravity aided by springs which accelerate the rods into the pile with high velocity.

In setting up the reactor safety control circuits, the following items were among the most important considerations :

(a) The maximum power level at which the reactor may be operated is governed principally by the ability of the cooling system to remove the heat produced. If the power level should suddenly rise above this maximum, then the pile must be shut down. As the power may rise almost instantaneously, measurement of thermal output to the cooling system is inadequate for safety control due to the time lag in temperature measurements. Therefore, ionization chambers which produce an instantaneous electrical signal directly proportional to neutron flux (power level) are used for safety control. One group of ionization chambers located in the thermal column is used with appropriate electronic amplifiers for automatic reactor control. Trip signals for over-power and excessive rate of rise of power are obtained from these amplifiers. In addition, a second group of ion chambers placed in a different position in the reactor are used for back-up protection on high power. These chambers are connected directly to sensitive relays with no intervening amplifiers so as to reduce the possibility of "no trip" due to instrument failure.

Ion chambers are very sensitive to neutron flux changes but they do not provide a sufficiently accurate measurement of the thermal power of the pile. For fine control of the reactor during normal steady-state operation, the ion chamber signal is automatically compensated by measurements of the temperature rise of the cooling water, thus giving a more accurate indication of the power output.

(b) Failure of the main electrical power supply, which would cause circulating pumps, air-conditioning plant, compressors, etc., to stop, must also give rise to an absolute trip and this is accomplished by relays actuated by the power-circuit itself.

(c) In certain circumstances a fuel rod may become distorted, causing the inner protective sheath to split. This would result in radioactive fission products being released into the cooling system and portions of the system would become contaminated.

When this occurs, a radiation detector trips the pile, stops the main pumps and transfers the cooling to an emergency system which carries the contaminated water into a large dump tank.

A device called a gaseous fission-products monitor is provided to sample the cooling water as it emerges from the bottom of each fuel rod. The gaseous fission products will escape to the cooling water before an actual rupture of the sheath occurs. These radioactive gases are detected by this monitor in the following way :

A sample of water is passed through a 'stripper' unit, where air is bubbled through it to strip out the gaseous fission products for passing to a beta counting head.

If the beta activity in the gas passes a certain predetermined level, an alarm is sounded and the split rod is identified on an annunciator panel in the control room. With the equipment provided it will be possible to set the alarms so that a warning may be given before the activity reaches a dangerous level, thus permitting removal of the damaged rod and preventing contamination of the cooling system.

(d) Failure of important auxiliary equipment which might lead to dangerous conditions on the pile or to health hazards to personnel will also trip the pile.

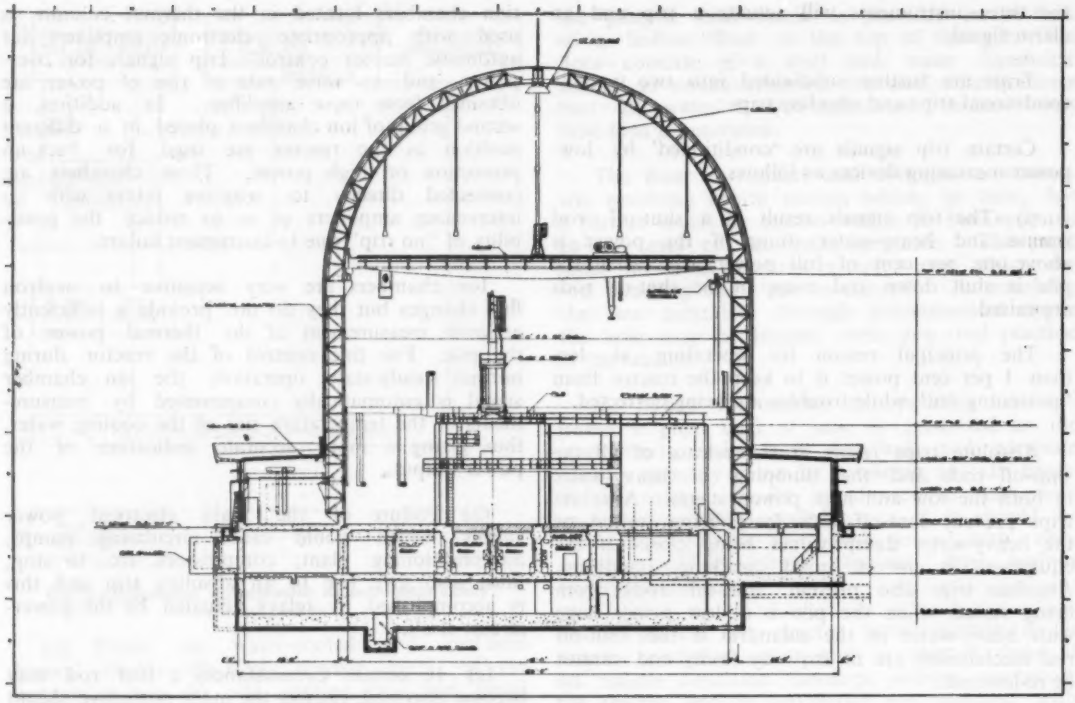


Fig. 2—Cross Section of Reactor Hall and Annulus.

In addition to failure of the main cooling pumps, as outlined above, failure or malfunctioning of the heavy-water pumps, sea-water pumps, or the air supply and exhaust fans will also trip the pile. High or low pressure, beyond the normal range of the cooling water at the bottom of a fuel road will also actuate the trip and alarm circuit as an indication of a fault affecting the flow of water through that rod.

Instruments connected to all parts of the process and mechanical equipment will, on a fault being detected, transmit signals capable of actuating trips or alarms or both, depending upon the nature of the fault and the importance of the equipment in question.

Pile Construction

To ensure that pile could be erected in its final location at the site without recourse to heavy machinery and other equipment for final adjustment, it is designed for preassembly at the plant of the manufacturer in Canada. Dummy fuel rods are provided to test the dimensional accuracy of each and every hole in the assembly.

The pile proper is carried on a heavy steel frame consisting of a machined assembly of welded plates and shapes supported on four heavy steel columns. On the supporting frame, the main floor plate of the reactor is fitted; this is a steel plate 6½ in. thick, 18 ft. 0 in. diameter. The floor plate supports the lower thermal shields which, in turn, support the calandria and the graphite reflector.

The main floor plate also supports the cast-iron side thermal shields and the peripheral ducts through which cooling air is supplied to and removed from the pile.

The upper thermal shields are supported by the shielding concrete surrounding the pile and by a steel structure provided to facilitate assembly; these support also the cast-iron webs into which the four removable biological shields are fitted and on which the 4 in. thick top master plate rests.

The top master plate is provided with the holes having bevelled shoulders on which the fuel and other rods are suspended in the pile. The master plate positions the rods at the correct spacing in the pile as determined by the characteristics of the reactor.

The upper cooling water header is supported by saddles on the master plate and is free to move radially as the four supply nozzles to the feed pipes are connected through expansion joints.

A cylindrical steel shell supporting the revolving floor above the pile, forms the upper header room which contains the upper ends of the fuel rods, the driving mechanism for the shut-off rods, and of course, the upper header itself.

The upper header room is connected to the shielded rooms by vertical chases in the shielding concrete. At the base of the pile the space beneath the main floor plate is called the lower header room and it also is connected to the shielded room by chases in the concrete.

The chases permit the pipes of loop experiments to be brought, from the ends of the assemblies in the piles, to the equipment set up in the shielded rooms.

The materials used in the steel shields, the top master plate, main floor plate and revolving floor are standard low carbon steels selected for weldability. To avoid cracking and to secure sound welds, low hydrogen electrodes are used and the completed weldments are stressrelieved before being machined, to prevent distortion.

The cast-iron side shields are of ordinary gray cast-iron, also stressrelieved before being machined to prevent distortion.

Wherever possible, standard materials are used and the manufacturing tolerances are kept as open as possible in order to keep the work within the range of good industrial practice.

In the past, attempts have been made to build reactors with a high order of precision, but experience with the NRX reactor has proved that the advantages of close tolerances are, in many cases, more apparent than real—even when they are attained in practice which is not quite as often as might be expected.

A feature of the upper thermal shields is the provision for removing tubes from the calandria without removing the upper shields. By mounting a heavy drill on top of the pile and drilling downwards, using a special technique developed by A.E.C.L. at Chalk River, it is possible to remove and replace damaged calandria tubes without dismantling the reactor.

In the removeable steel shields the tubes have extra thick walls to permit them to be bored out, to allow a calandria tube to pass through, without seriously weakening the shield. The tubes in the aluminum shield above the pile and the tubes in the removable biological shields are made large enough to pass the calandria tubes without drilling.

Experimental Facilities

Another important design consideration is the provision of experimental facilities in the pile which will permit the maximum possible use to be made of the high flux available.

The experimental facilities include the following:

(a) Thermal columns.

(b) Horizontal holes.

(c) Vertical holes.

(d) Self-serve holes.

(e) Central experimental hole.

(a) The thermal columns are used to obtain thermal neutron beams of high purity and large cross-sections; they are projections of the graphite reflector which extend horizontally through the shielding on the east and west axes of the reactor.

Each column consists of a stationary and a removable section of graphite. The stationary section is 5 ft. 0 in. square and extends from the reflector graphite to a point immediately outside the cast-iron thermal shields. The removable section extends to the outside of the shielding concrete and is separated from the fixed sections by a slot left to complete the cooling-air annulus between the two sections of the side thermal shields.

The removable section of the column is divided into three assemblies of graphite blocks, mounted on shallow-four-wheel trucks so that they may be removed from the reactor. The three movable assemblies are each 2 ft. 6 in. thick and 6. ft· 8 in., 6 ft. 3 in., and 5 ft. 10 in. square respectively.

The four sides of the thermal columns are enclosed by a cost-iron frame, 12 in. thick at the inner end of the movable section and diminishing by steps to 3 in. at the outer end. A clearance of 3/16 in. is provided between the movable sections and the cast-iron frames to allow passage of air. The cast-iron frames serve to support the weight of the removable sections and to protect the surrounding concrete from the damaging effects of radiations.

The graphite blocks in the removable sections are each 6 in. $\times$ 5 in. $\times$ 30 in. and certain pieces may be removed to vary the intensity of the neutron beam desired. A central block may be removed forming a hole extending all the way to the calandria shell and other blocks may be removed to form openings of various sizes.

The outer face of each thermal column is covered with a large vertical sliding door of lead and steel having a thin layer of cadmium on the inside surface. A small door, sliding in grooves in the main door is also provided.

In the east thermal column are located the ion chambers for power measurement and steady-state operating control of the pile.

(b) The horizontal holes extend from the outer face of the biological shielding concrete to the calandria shell. Each whole has a cast-iron inner door, which operates like a large plug-cock, located on the inner face of the biological shield. The gate is operated by a worm-drive shaft which extends to the reactor face. The outer end of each hole is provided with a lead gate operated by a hand-screw located on a cast-iron housing at the reactor face. Through these gates and doors equipment can be inserted into the pile without exposing personnel to excessive radiation.

The horizontal holes include the following:

(1) Twenty-nine experimental holes 4 in. diameter.

(2) Five experimental holes 12 in. diameter.

(3) Fourteen experimental holes 8 in. diameter; four of which contain the ion chambers actuating the low and high power trips for

pile control whilst the remaining twelve are available for future instrumentation or experimental purposes.

(4) Four horizontal holes 2⅛ in. diameter carrying temperature and pressure measuring instruments located in the J-rod annulus.

The experimental holes provide means of irradiating a few large samples or of obtaining neutron beams external to the reactor. The 'holes' consist of stepped holes extending through the reactor structure to the face of the calandria. They are lined with aluminum tubing in the graphite reflector and with steel tubing in the cast-iron thermal shields and in the biological shields.

When not in use for experimental purposes, the holes and plugs are cooled by a stream of air drawn into the J-rod annulus through the annular space around the plugs. When samples are being irradiated, however, additional cooling may be required and special arrangements are made to suit each particular experiment.

When the horizontal holes are not actually containing instruments or experiments, they are filled with temporary wooden plugs fitted with end sections of lead and cadmium; soft wood is used for this purpose as it forms satisfactory shielding and is relatively inexpensive.

(c) Six verticle holes are provided in the calandria, each having a diameter of 4 in. into which either standard fuel rods or loop experiments may be placed. In a loop experiment, test equipment is located in one of the shielded rooms and the material under test is circulated from the shielded room, through the pile and back to the shielded room. When these holes are used to contain normal fuel rods, special sleeves are provided in the upper thermal shields to reduce the size of the holes so as to prevent streaming of neutrons past the fuel rods.

(d) Six self-serve or sample units are provided, each fitted with a five-receptable plug, thus permitting a total of 30 samples to be irradiated at the same time.

The self-serve holes provide a principal means of producing radioactive isotopes. They are designed for the irradiation of small samples in the region of the graphite reflector and close to the calandria shell. The samples must be capable of enclosure in a 2¼ in. diameter aluminum sphere as they are allowed to roll to the carrying plug for insertion and to roll out to sample flasks for removal from the pile.

The units are provided with electrical and mechanical interlocks to prevent the insertion of more than one sample in one position and to avoid exposure of personnel to irradiated samples. They are so designed that the special shielded sample flasks must be in position at the discharge holes to receive samples before the carrying plug can be unlocked and the sample released.

(e) The central experimental hole in the pile, called the central thimble is 5½ in. diameter and is available for use where high neutron density and a high proportion of fast neutrons are required, and where a relatively large sample or experimental assembly must be accommodated.

This tube, when not in use, is also provided with a stepped plug (of steel) and the facility is cooled by air drawn from the process air system at the rate of approximately 90 cubic feet per minute.

Loop experiments of large size are also placed in this central thimble and connected to shielded rooms as described above.

The pile is also provided with a number of smaller holes and facilities for special experimental purposes, but the bulk of the work to be done with this reactor will be carried out on the facilities described above.

Rod Handling and Storge Equipment

As has been described, fuel rods are charged into the pile and discharged through a hole in the revolving floor. Whilst it is possible to lower a new fuel element into the pile by any convenient means, it is quite impossible to handle a spent or partly spent element in this way because the uranium section is so highly radioactive that exposure to personnel would result in death or serious injury.

All rods are therefore moved into and out of the pile by means of a vertical flask. A flask consists of a steel tube surrounded with sufficient lead to effectively stop any radiations from a fuel rod—even in its most dangerous condition.

The flask is mounted on an electrically driven carriage, and a portion of it is capable of being raised or lowered so that it can be positioned close to the pile floor to receive or discharge a rod. It can also be traversed across a bridge, shown in Fig. 2, to the storage block where rods can be discharged to or removed from storage.

The flask is designed to handle the central thimble plug and also a special adaptor for enclosing ruptured fuel rods and removing them from the pile. It is provided with manual hoists for raising and lowering the rods and with other facilities and flexible connections to permit them to be cooled after they have been removed from the pile.

Electrical and mechanical interlocks and other safeguards are provided to prevent fuel rods being removed when the flask is not in close contact with the floor and when personnel are in the upper header room.

The procedure when removing a rod is as follows: The pile is shut down to permit an operator to enter the upper header room for the purpose of disconnecting the normal cooling water supply and connecting a flexible hose from the flask above. At the same time, a flexible hose is connected to the lower end of the rod so that cooling

interruption is kept to a minimum. The operator then leaves the upper header room to a point where a key must be inserted in the interlock system before the fuel rod can be raised. The rod is raised into the flask and the temporary hose from the lower header room is disconnected; a hose from the storage block is then connected to maintain the circulation of cooling water whilst the flask carriage is moving to the storage block.

New fuel rods are stored in racks in the area adjacent to the storage block and are transported to the storage block by the monorail for loading into the flask.

Spent fuel rods are stored under water in a tank in the storage block. There they are left for several months to permit radioactivity to decay to the point where they may be further treated.

After a short period of storage in the full length condition, the rods are placed into an automatic sawing machine built into the storage block. This machine cuts off the portions above and below the uranium centre section and then strips the outer sheath from the remaining section of the rod. The uranium section, with its thin aluminum cladding, is then transferred to the wet storage tank until such time as it is desired to remove it for further processing.

The upper and lower sections of the rods are removed, and after cleaning and decontaminating they are re-used on other fuel rods.

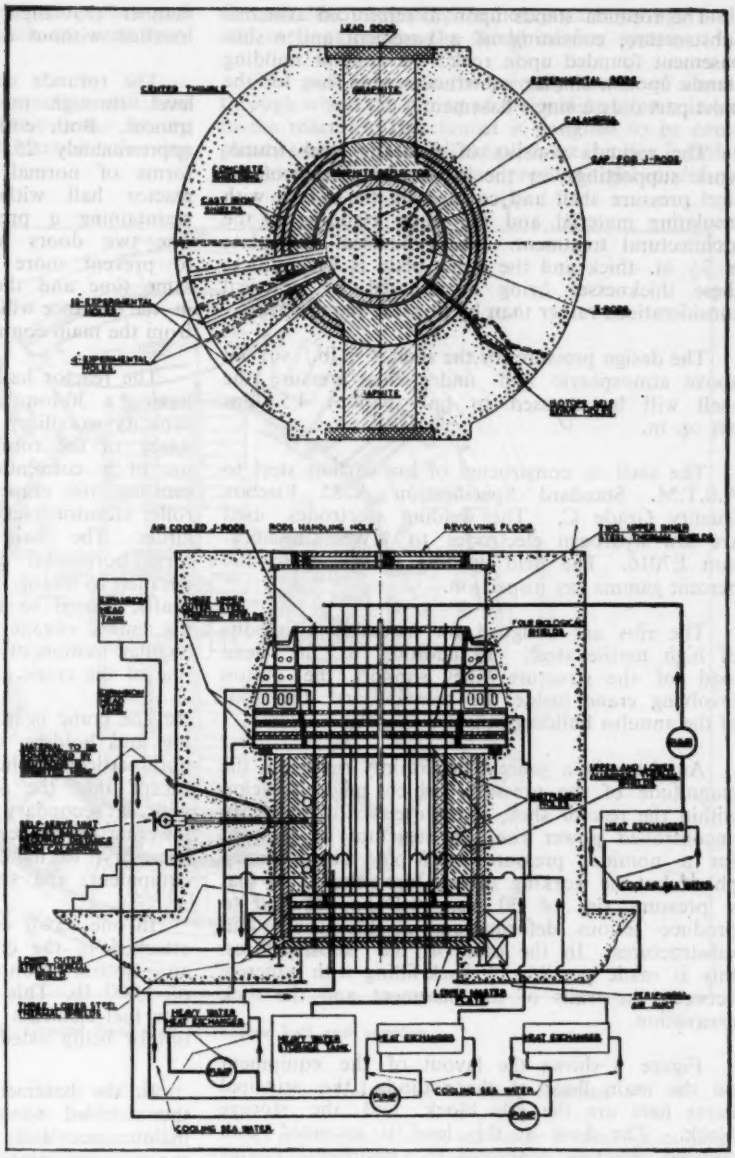


Fig. 3—Schematic diagram of reactor core and ancillary equipment.

The storage block contains also the following additional facilities:

(i) Horizontal holes for storing plugs and experimental assemblies from the horizontal holes in the pile.

(ii) Verticle holes for storing central thimble plug and ruptured rod flask.

(iii) X-ray equipment for radio-graphing irradiated fuel elements.

(iv) Facilities for loading and unloading samples in special 'tray rods'. These are used to irradiate small samples in fuel rod positions for the production of radio isotopes.

(v) Trench system connected to outside water-filled cutting bay for cutting and dismantling loop experiments.

Layout of Reactor Hall Rotunda

The general arrangement of the reactor building is shown in Fig. 2. The central rotunda contains the steel pressure shell, housing the pile and the storage block. The lower, annular, single storey building at the base of the rotunda contains all the auxiliaries and services not actually required at the pile itself.

The rotunda stands upon a reinforced concrete substructure, consisting of a basement and a sub-basement founded upon rock; the annular building stands upon a similar substructure, but has for the most part only a single basement.

The rotunda consists of a heavy steel framework supporting, on the inside, the plating of the steel pressure shell and covered on the outside with insulating material and the outer cladding of the architectural treatment. The cylindrical shell plate is ⅞ in. thick and the dome plate is ½ in thick, these thicknesses being necessitated by practical considerations rather than by pressure requirements.

The design pressure for the shell is 5 lb./ sq. in. above atmospheric and under this pressure the shell will be stressed to only about 4.5 kips per sq. in.

The shell is constructed of low-carbon steel to A.S.T.M. Standard Specification A285 Firebox Quality Grade C. The welding electrodes used are low hydrogen electrodes to AWS Classification E7016. The field welding is subject to 100 percent gamma ray inspection.

The ribs are designed for assembly with bolts of high tensile steel. In addition to the dead load of the structure, they support the 30-ton revolving crane inside the rotunda and the roof of the annulus building outside.

As there is a general uncertainty regarding the magnitude of the pressures which might develop within the reactor shell, in the event of a temporary uncontrolled power rise, the structure is designed for a nominal pressure of 5 p.s.i. above atmospheric but the working stresses are selected so that a pressure rise of 30 p.s.i. will be required to produce serious deformations in the shell and substructures. In the case of the substructures, this is made possible by back-filling with concrete between the walls of the basement and the rock excavation.

Figure 3 shows the layout of the equipment on the main floor of the rotunda; the principal items here are the pile block and the storage block. The floor at this level is provided with covered channels connected to a peripheral channel at the base of the shell, for the accommodation of temporary wiring and other services to instruments and experiments which may be set up around the pile block and round the periphery of the building.

In the experimental area around the pile, provision is made for experiments involving equipment and lead shielding equivalent to a superimposed loading of 6,000 lb. per sq. ft. Elsewhere, this floor is designed for a loading of 3,000 lb. per sq. ft.

In the main floor also are removable slabs which form the roofs of the shielded rooms in the basement below. Eight of these shielded rooms are provided, where loop experiments can be set up in which fluids may be circulated through the pile and through experimental equipment in the rooms, in such a manner that highly radioactive materials may be handled without danger to staff.

The rotunda can be entered only at this floor level, through the personnel and the vehicle entrances. Both entrances are fitted with airlocks approximately 25 ft. long inside; to permit all forms of normal traffic to enter and leave the reactor hall without violating the principle of maintaining a pressure-tight shell at all times. The two doors in each entrance are interlocked to prevent more than one being opened at the same time and the power supply to all the doors in the entrance will, in an emergency, be controlled from the main control room in the annulus building.

The reactor hall is serviced by a revolving crane having a 30-ton capacity main hoist and a 5-ton capacity auxiliary hoist. As the hemispherical dome of the rotunda is too high to permit the use of a conventional king-post, the problem of centring the crane is solved by attaching a heavy roller elevator-bucket type chain to the crane rail girder. The chain is arranged so that the rollers form horizontal rack teeth on a circular path parallel to crane rail. Sprockets with horizontal shafts, geared to the drive wheels at each end of the crane, engage the rack teeth and ensure equal angular motion of the end trucks about the centre-line of the crane.

The crane is fitted with normal hoisting, lowering and holding brakes and all the movements, both vertical and horizontal, are at standard speeds; except that the 5-ton auxiliary hoist is provided with a secondary drive to permit hoisting and lowering at a speed of 1 foot per minute, when necessary, to handle fuel elements, experimental equipment, and so on.

In one sector of the building, a light monorail is attached to the crane rail beam to accommodate an electric monorail hoist, having a capacity of 1,000 lb. This monorail will be used to handle new fuel elements which are either under construction or being tested prior to insertion in the pile.

In the basement are situated, in addition to the shielded rooms, a utility room for the use of maintenance and other personnel; a monitoring room containing flow monitoring equipment from the fuel rods and a room containing the heavy-water heat exchangers which must of necessity be placed close to the pile in order that the pipe-runs may be limited to conserve the amount of heavy-water required.

The sub-basement contains ventilating and air-conditioning ducts, power and instrumentation cables and service piping generally and will not be used for experimental or similar purposes.

The main floor of the annulus building is at the same level as the main floor of the rotunda and contains the control room, the vehicle and personnel entrance airlocks; air-conditioning plant; the main fresh water cooling pumps, the power supply distribution board and battery room; the motor control centre; the helium purification plant,

together with part of the water treating plant and an experimental room in line with the west thermal column.

The area containing the main-pumps and heat exchangers is serviced by a 10-ton crane having electrical hoisting machinery and manual traversing movements.

the annulus, containing the heavy-water salvage tank and catch tanks for the shield cooling systems.

The pipe tunnel is the primary means of access, through which the piping of the cooling circuits is led to the reactor. This tunnel is designed to be completely sealed off after all the pipes are in place in order to maintain the basement in a pressure-tight condition.

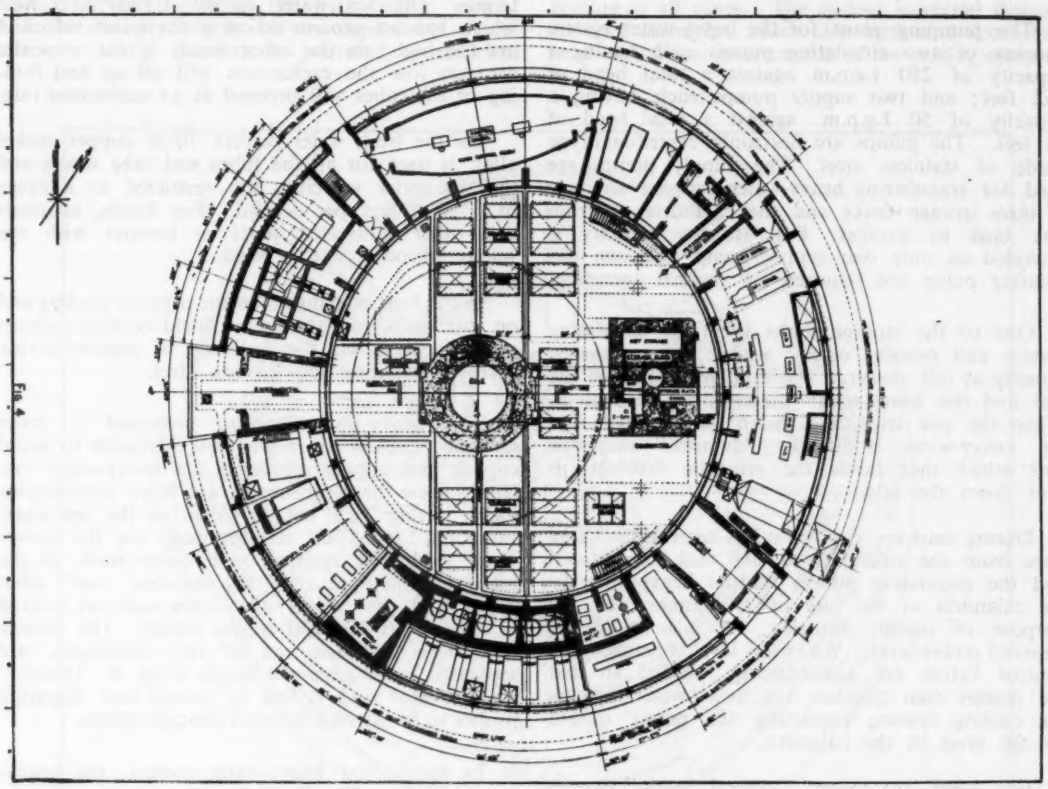


Fig. 4—Ground floor plan of reactor hall and annulus.

In the basement of annulus building, the heat exchangers are situated below the main pump room and the centrifugal compressors of the air-conditioning plant are located below the air-conditioning unit. The heavy-water tanks, heavy-water pumps, and the helium gasholder are located below the helium purification unit. In the room beneath the control room all the leads and wiring connected to the process and other instruments are collected on trays and lead up to the panel boards and console in the control room and to the trip and alarm panel in the room adjacent to the control room.

The basement also contains the ion exchange columns and deaerators of the water treating plant, together with the compressed air plant, main exhaust fans, air filters and the access chambers leading to the filter compartment.

Adjacent to a pipe tunnel on the west side of the rotunda basement is a small sub-basement under

Details of Cooling System

As mentioned above, sea-water is used for cooling the reactor. Fresh water is circulated through the pile and water-cooled shields in closed circuits and transfers heat to sea-water in heat exchangers located in the annulus. The heavy-water circulates in another closed circuit and is cooled directly by sea-water in heat exchangers located in a shielded room in the basement adjacent to the pile.

The primary cooling system has six heat exchangers arranged so that any number can be operated together in parallel. Under maximum normal operating conditions there are five units operating and one on standby.

The pumping plant for the primary cooling system consists of five horizontal centrifugal pumps each having a capacity of 1200 I.g.p.m. against a total head of 560 feet. These pumps have cast-iron bodies and bronze impellers.

The steel and aluminum shield cooling systems each consists of two heat exchangers, one operating and one on standby.

On the heavy-water system there are three heat exchangers arranged so that any number can be operated together in parallel; the system is designed so that two units only are required for the maximum operating conditions with one unit on standby.

The pumping plant for the heavy-water system consists of two circulating pumps each having a capacity of 250 I.g.p.m. against a total head of 162 feet; and two supply pumps each having a capacity of 50 I.g.p.m. against a total head of 76 feet. The pumps are horizontal centrifugal type made of stainless steel. The supply pumps are used for transferring heavy-water between any one of three storage tanks and the calandria or from one tank to another. Full standby capacity is provided as only one supply pump and one circulating pump are required for normal operation.

One of the storage tanks is in the circulating system and remains empty whilst the reactor is running at full power. The tank forms part of the line and the heavy-water merely flows through it. When the pile trips, the dump valves open and the heavy-water is literally "dumped" into this tank which then holds the requisite amount to shut down the pile.

During start-up, control valves on the discharge lines from the calandria to the tank are closed and the circulating pumps transfer heavy-water to the calandria at the rate of 250 g.p.m. for the purpose of rapidly bringing the pile up to the required power level. When this level is reached, the control valves are automatically opened so that the pumps then circulate the heavy-water through the cooling system, regulating the power output by the level in the calandria.

For what are termed "critical height" experiments, control of the level of heavy-water in the calandria is maintained by the overflow of heavy-water through a wire box which can be raised or lowered accurately to any height depending upon the power level at which the reactor is required to operate.

All valves, pipes, pumps and tanks in the heavy-water system are of stainless steel, to ensure absolute freedom from corrosion and consequent contamination of the system by irradiated corrosion products.

All heat exchangers are of the shell and tube type and are mounted vertically with floating heads at the lower end of the tube bundles. All the heat exchangers are arranged so that the tube bundles can be removed without dismantling the shells and in each set of identical exchangers the tube bundles are interchangeable.

In all cases, the sea water passes through the tubes, which are ¾ in. diameter and straight to facilitate cleaning. The sea water is chlorinated at the intake to inhibit the formation of marine growths. Experiments carried out near the site indicated that chlorine injected continuously in sufficient quantities to provide a residual chlorine content of 3 p.p.m. one half hour after injection would prevent serious fouling by marine growth under the most adverse monsoon conditions.

One of the problems in the design of the heat exchangers was the selection of suitable materials. The sea water carries a heavy silt load which has an erosive action if the water velocities are too high; on the other hand, if the velocities are too low the exchangers will silt up and fouling of the tubes will proceed at an accelerated rate.

On the fresh water coolers 70:30 copper nickel alloy is used for all the tubes and tube sheets and the sea water velocities are restricted to a range of 3 to 6 feet per second. For heads, channels and other fabricated parts in contact with sea water, silicon-bronze is used.

In the heat exchangers on the primary cooling and on the steel and aluminum shield cooling systems using fresh water, the shells are of copper-bearing corrosion-resisting low carbon steel.

The heavy-water coolers presented a more difficult problem as it was felt advisable to avoid copper and copper alloys in the heavy-water system. These heat exchangers are fitted with duplex tubes, having 70:30 copper nickel on the sea water side and type 304 stainless steel on the heavy-water side. The stainless steel outer walls of the tubes terminate in type 304 stainless steel tube-sheets and the copper alloy inner walls are secured in tube-sheets of 70:30 copper nickel. The double tube-sheets at each end of the exchangers are separated by air gaps and spacer rings of "Inconel" are provided and drilled to permit leak detecting probes to be inserted between the tube-sheets.

In the special heavy-water coolers, the heavy-water is exposed only to stainless steel and the sea water to 70:30 copper nickel or to silicone bronze. No dissimilar metals are connected together in the presence of a common electrolyte so that galvanic corrosion will not be a hazard.

On the fresh-water coolers the sea-water is exposed only to 70:30 copper nickel alloy and silicon bronze and the fresh-water is exposed to the copper alloy tubes and tube sheets and to the corrosion-resisting steel in the shells. Where dissimilar metals are connected together in the presence of a common electrolyte, they are insulated by means of Neoprene gaskets and the bolts securing the dissimilar metals are provided with insulating sleeves and washers.

The upper and lower headers and the supply pipes embedded in the pile concrete are of stainless steel. Stainless steel has been selected for the headers because mild steel will rust on the outside in the moist conditions created by leakage of water from the rod connections and contamination of the rusty headers would make maintenance difficult. The embedded pipes are of stainless

steel because they are totally inaccessible for maintenance after the pile concrete has been poured.

Type 347 stainless steel is used for the headers to permit them to be given a thermal stress-relief treatment during manufacture. Type 304 stainless steel is used for the embedded supply pipes.

Fresh water for the closed circuit main cooling system is supplied from the city water mains; but, as the city supply is not dependable at all times, a storage reservoir is provided of sufficient capacity to supply cooling water to the pile in an emergency for approximately four weeks with the pile operating under shut-down conditions.

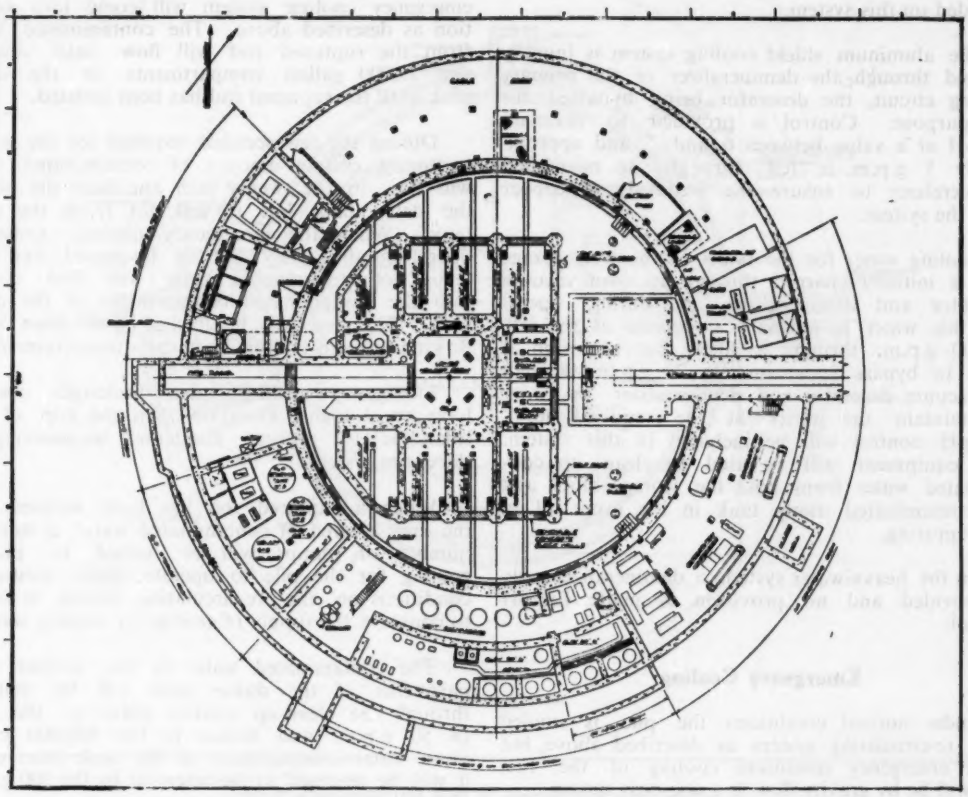


Fig. 5—Basement plan of reactor hall and annulus.

Delay System

Although the cooling water is continuously treated during pile operation to remove impurities, certain isotopes having very short half lives are produced. To prevent a dangerous build-up of activity in the cooling water, a delay system is provided to permit the cooling water to remain outside the pile for a pre-determined length of time.

This delay system consists of a 5 ft. diameter pipe 800 ft. long, in the form of a large 'U' (to save ground space). The pipe has a capacity of one hundred thousand gallons, thus providing a delay of 20 minutes with a flow of 5000 g.p.m.

The delay pipe is located at the foot of a nearby hill, directly under the storage reservoir. The entire system of delay tank and connecting pipes slopes upwards away from the pile to provide positive drainage when required and positive venting at all times. The system is vented through an open standpipe which also maintains a constant head on the low pressure side of the cooling system.

Twenty-inch diameter mild steel pipes connect the delay pipe to the pile; the delay pipe itself is constructed of low alloy corrosion-resisting steel (U.S.S. Corten).

Normal flow of cooling water is from the pumps to the fuel rods, through the delay tank, through the heat exchangers and back to the pump suctions, thus providing a total delay of a little over half an hour.

Water Treatment Plant

Water for the primary cooling system is initially charged into the system by feeding city water through a vacuum deaerator and a demineralizer

bed until the system and the storage reservoir have been completely filled. During operation, approximately 100 gallons per minute is fed through the vacuum deaerator and demineralizer bed to maintain the purity of the water at the required level. Control is provided to maintain the pH between the value of 6 and 7.

Water for the steel shield cooling system is charged into the system through a deaerator and demineralizer of the primary cooling circuit. The system is controlled to maintain the pH at a value between 9.5 and 10.5 and sodium sulphite is injected to remove dissolved oxygen. No demineralizer is provided on this system.

The aluminum shield cooling system is initially charged through the demineralizer of the primary cooling circuit, the deaerator being bypassed for this purpose. Control is provided to maintain the pH at a value between 6 and 7, and approximately 5 g.p.m. is fed through a mixed-bed demineralizer to ensure the removal of copper from the system.

Cooling water for the tanks of the wet storage area is initially charged through its own vacuum deaerator and demineralizer, and during operation this water is normally circulated at the rate of 100 g.p.m. through a filter, but provision is made to bypass approximately 20 g.p.m. through the vacuum deaerator and demineralizer in order to maintain the purity at the required level. No pH control will be included in this system. This equipment will be used to clean up contaminated water from both the storage block and the contaminated dump tank in the event of a rod rupturing.

On the heavy-water system, a demineralizer only is provided and no provision is made for pH control.

Emergency Cooling

Under normal conditions the pile is cooled by a re-circulating system as described above, but under emergency conditions cooling of the fuel rods will be by gravity flow in a one-pass system.

Failure of the main pumping system or a ruptured fuel rod will cause the pile to trip and also automatically bring the emergency cooling system into operation. For this purpose a storage reservoir of 850,000 gallons is provided on the side of a nearby hill. An additional storage of 150,000 gallons is maintained for fire protection.

An emergency dump tank of one million gallons capacity is located at an elevation below that of the lower header of the pile and remains empty during normal operation of the main cooling system.

This dump tank is provided with compartment so that if the emrgency system is dealing with a ruptured rod the contaminated water will be isolated from the rest of the tank which must be kept clean to receive water from the pile during emergency cooling due to pump failure alone.

The main 850,000 gallon storage reservior rides on the high-pressure side of the system through a check valve, normally kept closed by the 240 p.s.i. pump pressure. Should the pump pressure fall below approximately 50 p.s.i., the check valve will open and a second, automatically operated, valve above the emergency dump tank will also open, permitting water from the reservoir to flow by gravity through the pile and into the dump tank.

If a rod splits, the fission products monitoring system will trip the pile and shut down the main pumps. Tripping the pile and pumps in this way will result in a loss of pressure and the emergency cooling system will come into operation as described above. The contaminated water from the ruptured rod will flow into one of two 75,000 gallon compartments in the dump tank until the ruptured rod has been isolated.

During the few seconds required for the pumps to stop, a certain amount of contaminated water will flow in the twenty inch line from the pile to the delay tank but it will not reach the delay tank. When the emergency cooling system is operating the delay line is by-passed and the "slug" of contaminated water will flow directly into the contaminated compartment of the dump tank. The line will be flushed with clean water flowing through the pile from the storage reservoir.

Emergency cooling water discharges over a loop at a higher elevation than the top of the calandria to prevent accidental un-watering of the entire system.

When a ruptured rod has been isolated and the lines cleared of contaminated water, a sufficient number of pumps will be started to provide cooling for the pile to operate, under shut-down conditions on the re-circulating system in order to conserve the supply of emergency cooling water.

The contaminated water in the smaller compartments of the dump tank will be pumped through the clean-up treating plant at the rate of 50 g.p.m. and thence to the 850,000 gallon clean water compartment of the tank from where it will be returned to the reservoir by the 300 g.p.m. pumps provided for that purpose.

The maximum flow obtainable from the emergency supply is 1400 g.p.m., so that ample cooling will be provided, since only 30 per cent of the normal flow is required one second after shut-down. As the heat load falls off still further, with increasing time of shut-down, the flow will be regulated and reduced still more to provide sufficient cooling water for four weeks operation under shut-down conditions.

As a pile trip will automatically cause part of the heavy-water to be dumped into its own tank, it is not necessary to provide emergency cooling for the heavy-water. Similarly, the steel and aluminum shields will generate almost no heat under shut-down conditions so that it is not necessary to provide emergency cooling for the water-cooled shields.

Sea Water System

The sea water carries an unusually heavy silt load, which increases considerably during the monsoon season when surface material is carried down from the surrounding hills by the heavy rains.

The sea bed slopes very gently downwards, away from the shore line, and is covered with a layer of mud approximately 15 ft. thick. The water off the site is so shallow that it is necessary to go out approximately 3500 feet from shore to secure sufficient depth of water for pumping.

As the sea area off shore from the site is a turning ground for oil tankers arriving at a nearby oil dock, the choice of site for the sea water intake was somewhat restricted.

The pumping station consists of a caisson having three compartments; two compartments being screening chambers and the third containing the pump suctions. Water enters a screening compartment through a coarse screen and a gate in the wall of the caisson and flows through a second gate and a second finer screen into the pumping chamber. From there it is pumped into the main pipeline. When one screening chamber requires cleaning its gates will be closed and water will be passed through the other one into the pumping chamber.

For the pile cooling requirements four vertical centrifugal pumps are provided, each having a capacity of 2700 g.p.m. against a total head of 120 feet. Only three pumps are normally required, the fourth being standby. A fifth pump will be installed later to supply additional cooling water for loop experiments and this will be idenitcal with the main pumps and will, of course, discharge into the same header and pipeline. The sea water pumps have nickel cast-iron bodies; Monel impellers.

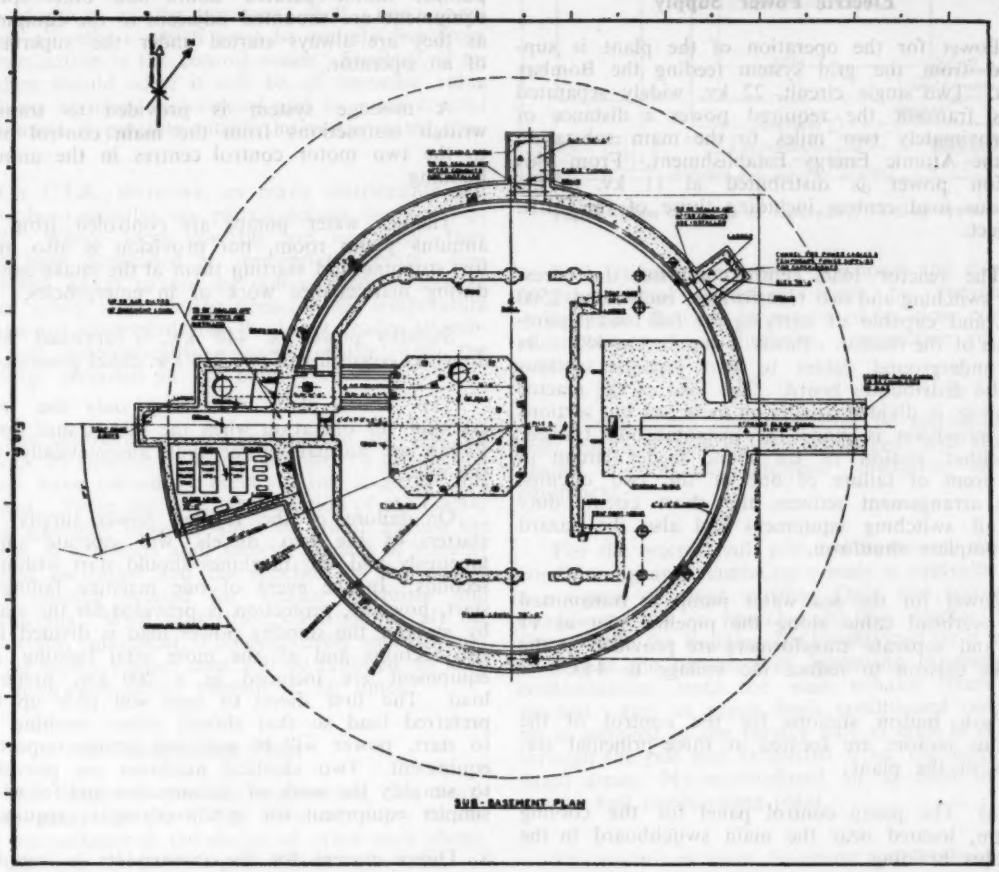


Fig. 6.—Sub-basement plan of reactor hall and annulus.

To prevent fouling of the system, by silt settling out of the sea water during shut-down periods, by-pass lines are provided to permit the sea water lines to be flushed before the heat-exchangers are brought into operation.

Chlorination of the sea water is carried out at the intake as outlined above in the description of the cooling system.

The pipeline to the shore is a welded steel pipe, lined inside with concrete. The pipe is carried on a pier of reinforced concrete constructed on the rock of the sea bed.

For the disposal of return sea water, a pipe is carried from the reactor to the sea wall where the return flow discharges into an open channel.

Electric Power Supply

Power for the operation of the plant is supplied from the grid system feeding the Bombay area. Two single circuit, 22 kv. widely separated lines fransmit the required power a distance of approximately two miles to the main substation of the Atomic Energy Establishment. From this station power is distributed at 11 kv. to the various load centres including those of the C.I.R. project.

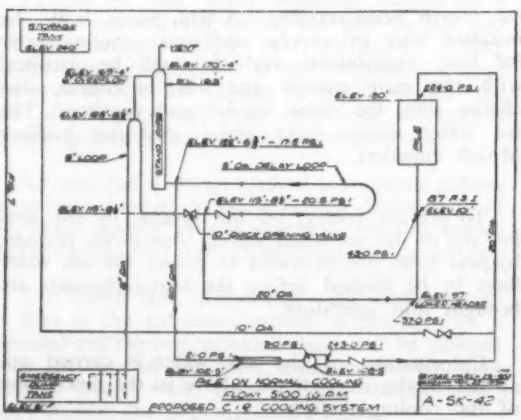
The reactor load centre comprises the necessary switching and two transformes, each rated 2500 kva. and capable of carrying the full load requirements of the reactor. Power is supplied at 440 volts by underground cables to two separate sections of the distribution board. The load of the reactor building is divided equally on these two bus sections and provision is made for instantaneous transfer of either section to the sound feeder circuit in the event of failure of one of the two circuits. This arrangement reduces the short circuit duty on all switching equipment and also the hazard of complete shutdown.

Power for the sea water pumps is transmitted via overhead cable along the pipeline pier at 11 kv. and separate transformers are provided at the intake caisson to reduce the voltage to 440.

Push button stations for the control of the various motors are located at three principal stations in the plant:

(a) The pump control panel for the cooling system, located near the main switchboard in the annulus building.

Fig. 7.—Flow diagram of normal primary cooling system.



(b) Control panel for all fans, pumps and compressors of the airconditioning and exhaust system, located in the air-conditioning plant room in the annulus.

(c) Heavy-water pump controls located in the main control room.

Push-button starters for air-compressors sump-pumps, motor-operated doors and other special equipment are mounted adjacent to the equipment as they are always started under the supervision of an operator.

A message system is provided to transmit written instructions from the main control room to the two motor control centres in the annulus building.

The sea water pumps are controled from the annulus pump room, but provision is also made for stopping and starting them at the intake caisson during maintenance work or in emergencies.

Standby power of 440 kw. is furnished by a diesel set consisting of two 220 kw. diesel generators.

The diesel plant will carry only the loads essential for operation when the pile is shut down. Failure of normal power will automatically trip the pile.

On failure of the regular power supply, the starters of the two diesels will operate simultaneously and the machines should start within 15 seconds. In the event of one machine failing to start, however, protection is provided for the standby system; the standby power load is divided into two sections and all the more vital lighting and equipment are included in a 200 kw. preferred load. The first diesel to start will pick up this preferred load so that should either machine fail to start, power will be available for the important equipment. Two identical machines are provided, to simplify the work of maintenance and for which simpler equipment for synchronizing is required.

Direct current for the instruments is supplied by motor generator sets with storage batteries 'riding on the line' to supply current in the event of a power failure.

Control Room

The main control room is located in the annulus building and contains all the instruments and control devices necessary for the proper and efficient operation of the reactor. On a large graphic panel are shown simplified flow diagrams for the heavy-water, helium, primary cooling and shield cooling systems, on which miniature instruments are mounted to show the relation of each to the process.

Adjacent to the control room is an instrument room containing the trip and alarm panels and other panels for which constant attention by the operator is not required, and an office and cloakroom for the convenience of shift operators.

The control room is not accessible directly from the reactor hall as there is nothing to be gained by being able to look into the pile building from the control room and, in fact, windows or any means of access between the two rooms would constitute a definite weakness and would defeat the object of the pressure shell.

If an incident should occur which would justify the adoption of the pressure shell, one room above all others which must be entirely free from contamination is the control room. Similary, if an incident should occur it will be of immense value to have as many instruments and as much control equipment a possible outside the contaminated area.

On C.I.R. therefore, as many instruments and controls as possible are placed outside the pressure shell. Where local controls are necessary, they have been duplicated at appropriate points. Instruments which cannot be conveniently located in other areas, such as the pressure and temperature measuring instruments for the lower header assembly, are automatically scanned locally and the readings recorded in the control room.

The centralization of controls in as few locations as possible is made necessary by two factors which have influenced much of the design of this project. These are, first, the isolation of the reactor in a gas-tight pressure shell to guard against the effects of accidents and, second, the lack of suitably trained personnel and the function of the project as a training ground for Indian scientists and technicians. With centralized controls for all the important equipment, a comparatively smaller number of highly trained men will be required to keep the equipment under control at all times.

Air-Conditioning Plant

The design of the air-conditioning and ventilating plant for the C.I.R. involved many factors not encountered in the design of other such plants. In addition to providing sufficient quantities of cooled and dehumidifield air to meet comfort requirements in the building, the system is required to provide positive and extremely reliable ventilation to both the occupied areas and the pile itself.

Sufficient air must be drawn through the pile to remove the heat equivalent of about 200 kw. in the regions of the thermal shields and J-rod annulus. Air pressures within the pile itself must be held below those in the experimental areas surrounding it so that all air leakage will be inwards. All contaminated areas must be liberally ventilated to prevent dangerous build-up and escape of radioactive air.

All contaminated air must be efficiently filtered and discharged from the reactor building in a manner which will not create a health problem and will not increase the background radiation in other experimental areas of the Establishment.

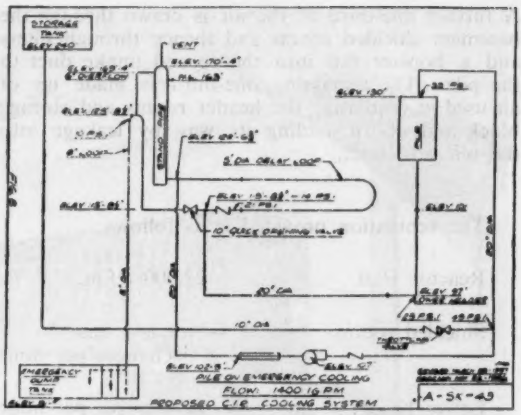


Fig. 8—Flow diagram of emergency cooling system.

Both fatigue of operating personnel and damage to experimental equipment must be prevented, in so far as they can be prevented by close control of temperature and humidity, irrespective of the outdoor climate.

All the above objectives mut be accomplished with adequate and reliable safeguards and alarms against faulty or abnormal operation of the equipment.

For the reactor hall, pile and basement, the air-conditioning and ventilating system is equivalent to a one-pass or series system. Only one source of conditioned air is provided to the reactor hall. Once inside the building the conditioned air is made to flow in the direction of increasing exposure to contamination, until the main exhaust filters are reached. Just as much fresh conditioned outdoor air is supplied to the reactor hall as must be drawn through the pile and exhausted from the contaminated areas. No re-circulated air is used in the reactor hall conditioning plant.

The reactor rotunda, basement and sub-basement areas are maintained continuously at a positive pressure of 0.5 in. w.g. with respect to the outside temperature; this provides improved control of the air motion and facilitates balancing the various ventilating systems within the building, especially those connected to contaminated areas and it also prevents the infilteration of untreated air.

Air is filtered and conditioned in the central conditioner, located in the annulus, at a rate of 24,000 cubic feet per minute. Of this, 22,000 c.f.m. are discharged through a duct and a (normally open) automatic pressure damper into the reactor hall and 2,000 c.f.m. are diverted to serve the fresh air requirements of certain rooms in the annulus building.

Approximately one-thired of the air supplied to the reactor hall is drawn through secondary filters and into the pile through one of two intake ducts.

A further one-third of the air is drawn through the basement shielded rooms and thence through filters and a booster fan into the second intake duct to the pile. The remaining one-third is made up of air used in ventilating the header rooms and storage block and of air finding its way by leakage into the pile structure.

The ventilation provided is as follows:

Reactor Hall	—22,000 c.f.m.
Shielded rooms	—Not less than 10 changes per hour
Lower header room	—22 changes per hour
Upper header rooms	—28 changes per hour
Storage block openings	—min., velocity of air 100 f.p.m.

Air (withdrawn from the pile header rooms and storage block), originally conditioned but now contaminated, is drawn through an exhaust duct and a second (normally open) automatic pressure damper to the filter compartment.

The filter compartment is located in the annulus diametrically opposite the conditioner location. It contains four parallel banks of absolute filters, with each filter element supported in a specially constructed pressure-type frame designed to eliminate air leakage past the filtering media.

Air leaving the filters is discharged to the stack through either one of two identically rated electric motor-driven blowers, each capable of handling the total exhaust air requirements. A mechanical shut-off damper is provided on the upstream side and a water-seal is provided on the discharge side of each blower to facilitate maintanance of the fans and motors.

In the annulus building the main concern is with air conditioning and ventilating for the comfort of the occupants. A few of the annulus rooms are regularly occupied and in the tropical Indian climate some measure of cooling is desirable. The control room has its own air-conditioning plant which, like the reactor hall conditioner, is capable of providing independent control of both dry bulb temperature and humidity. Unlike the reactor hall system, however, the control room conditioning system is designed to take full advantage of the economies associated with the utilization of re-circulated air.

In the remaining areas where cooling is required, that is, the exhaust fan motor room, electrical equipment room, switchboard room and air-conditioning equipment room, ceiling suspended unit coolers are used.

A central refrigerating plant has been provided to serve the total cooling and dehumidifying requirements of the reactor hall and conditioned annulus rooms. It consists of two, identically rated self-contained, water chilling machines, operating in paralled and delivering water at a temperature of 46 deg. F. to the conditioners and unit-type coolers strategically located throughout the conditioned areas. The rated capacity of each machine is 130 tons of refrigeration.

Conditions at the site are such that for the five year period 1951 to 1955 inclusive, the daily maximum temperature recorded at Santa Cruz Air-port near Bombay reached a value above 80 deg. F. on 1785 days; that is an average of 357 days each year. An analysis of the meteorological data has shown that it would be most unwise to have designed for a wet bulb temperature of less than 84 deg. F. with a simultaneous dry bulb of 92.5 deg. F.

The humidity in the area is such that under certain conditions it is necessary to heat the air before delivering it to the conditioned zone, for if air were to be delivered to the occupied zone at the temperature required to lower the humidity to the design figure of 50 per cent, the dry bulb temperature would be considerably below the figure of 75 deg. F, adopted as standard for the occupied zone. This would result in a serious health problem.

Amongst the most important areas serviced by the ventilating plant are the upper and lower header rooms and the storage block, and the ventilation of these three sources of contamination must be adequate under all conditions.

The upper and lower header rooms and the storage block are connected to a common exhaust system which joins with the main exhaust duct from the pile in a plenum chamber located above the main exhaust duct and adjacent to the sub-basement wall normally, the suction head for this exhaust system is provided by the two main exhaust fans in the annulus.

In the event of failure of the main power supply, the quantity of air handled by the main exhaust fans will be reduced by lowering the fan speeds to avoid excessive loading on the standby power plant. Reduction of the main fan speed, however, inevitably leads to a reduction in the suction head on the upper and lower header rooms and storage block ventilating ducts with a consequent reduction in the ventilation of these areas. A small booster fan is therefore, located in the sub-basement plenum and under normal operating conditions it is by-passed, but on

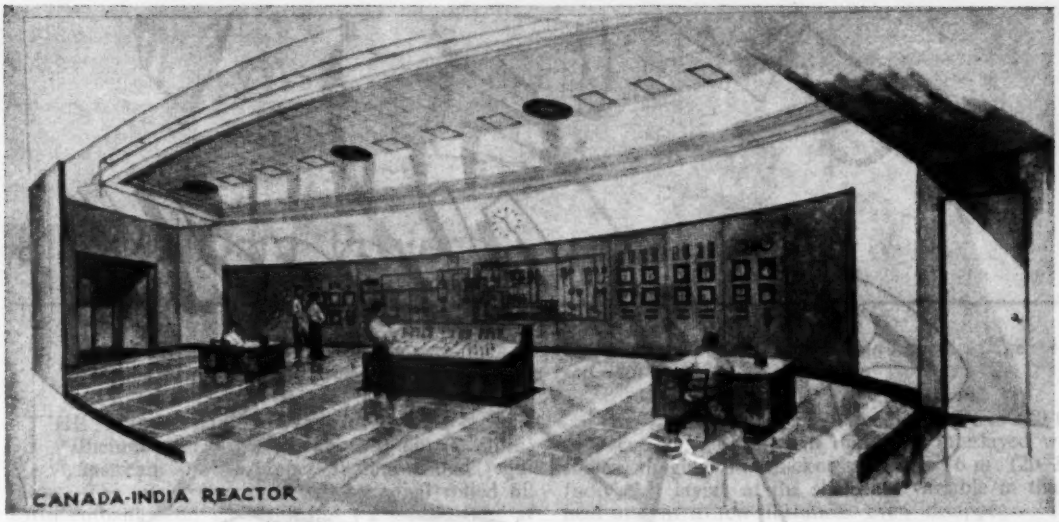


Fig 9—Control room.

interruption of the main power supply, it will start up and run on standby power. By this means the storage block and the upper and lower headers are adequately and continuously ventilated irrespective of the condition of the main power supply.

All the annulus areas which are not air-conditioned are positively ventilated with filtered outdoor air. Contaminated exhaust air from such areas as the heavy-water storage and salvage rooms, ion exchange and deaerator rooms, etc., is drawn through the absolute filters already described and discharged to the stack by the main exhaust blowers.

Acknowledgments

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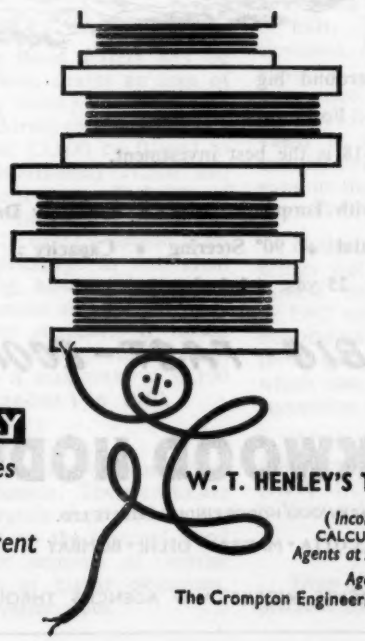

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Mangla Dam Project

The Mangla Dam Project has been very much in the news lately as its site is in Kashmir. The following features of the project will therefore be read with great interest—Editor.

THE Mangla dam will be located across the Jhelum river, figure 1, about 3 km (2 miles) upstream of the Upper Jhelum Canal regulator. The main structure will be zonal rolled fill earth embankment, almost 3 km (2 miles) long at the crest elevation which is 360 m (1,200 ft) above sea level. Its height at the deepest section from rock to crest would be about 108 m (360 ft). The reservoir so created will have an effective capacity of 4,317 million m^3 (3.5 million acre-ft).

The dam will be flanked by a power plant on the left and a spillway structure on the right. The power house will have an installed capacity of 300,000 kW (4 sets of 75,000 kW each), the power head varying between 54.9 m (180 ft) and 96 m (315 ft). The tail race will outfall into the Upper Jhelum Canal.

The spillway will be for a routed flood of 28,310 m^3/sec (1,000 cu. ft/sec) capacity. It will be fitted with automatic gates. The water will shoot from the end of the structure, and after falling in a trajectory about 60 m (200 ft) vertically, will flow back into the river Jhelum.

Hydrology

The Jhelum river whose flood waters will be conserved by the Mangla Dam, drains an area of about 33,700 km^2 (13,000 sq miles) above the dam site. The flow varies widely during each year, from a minimum of about 142 m^3/sec (5,000 cu ft/sec) to a recorded maximum of approximately 21,520 m^3/sec (760,000 cu ft/sec). The average discharge of the river at Mangla during the past 32 years was 895 m^3/sec (31,600 cu ft/sec) or 22.9 million acre-feet per year). The actual discharge in individual years varied widely, depending, however, both upon the snow pack on the mountain and the intensity of the monsoon rains in the summer. It varied from a minimum of 15,840 million m^3 (12.84 million acre-feet) in 1946 to a maximum of 39,190 million m^3 (31.77 million acre-feet) in 1950.

Geology

All the rocks in the Mangla area are sandstones and shales of the Siwalik formation. These rocks are covered by silts, sands and gravels deposited by the river within its channel and on the adjacent flood plains, and there are older deposits of similar material occuring in terraces at higher elevations, and as thin mantles on the valley sides.

The sandstones occur as beds from 6 m (20 ft.) to over 30 m (100 ft.) in thickness, interlayed with shales ranging in thickness up to 6 m (20 ft). Individual layers of the shale are variable in thickness and in a few instances even disappear. The thicker beds of sandstone are generally persistant. All of these beds dip from 5 degrees to 15 degrees to the north-east. In the adjacent areas in the Siwalik formations there are marked variations in strike and dip, indicating concentrated deformation of the strata, doubtless involving faulting. However, no faulting is evident at the dam site. Detailed studies show that the geology of the site is fit to support the proposed dam.

Storage

The storage capacity of a site depends upon three considerations: (a) geological, (b) topographical and (c) hydrological. Geologically, the site is suitable for a dam higher than the proposed one but for the limitations under the remaining two conditions.

Topographically, the southerly rim of the reservoir basin above Mangla is formed by a low range of hills. The crest of the ridge is rarely above elevation 350·52 m (1,150 ft) and the gaps below elevation 365·67 m (1,200 ft) aggregate several kilometres in length. This condition places a practical limit on the capacity which can be provided in the Mangla Reservoir. Long and substantial embankments will be required to close the gaps in the low ridge forming the southerly rim of the reservoir.

Hydrologically, the flow record of the river brings out the fact that years of less than average run-off tend to occur in groups, such as 1939 to 1942 and 1945 to 1948. This point is of extreme importance because the dependable supply of water for irrigation and power is limited by the supply which can be regulated and made useful during a succession of dry years.

After careful consideration of all the factors the full reservoir level has been set at elevation 359·05 m (1,178 ft). This provides a gross capacity of 5,057 million m^3 (4·1 million acre-feet).

Design of the Dam

Even if it were not for geologic conditions which preclude the use of a masonry dam, the topography

of the dam site is such as to make an embankment type of structure advisable. The design of the dam, therefore, is as a matter of course governed by the availability of materials close to the site. The test pits and diamond drill holes show that the sandstone and shale beds underlying the dam are at or fairly close to the surface. Hence, the preliminary design of the dam has been based upon carrying the central impervious core to contact with the bed-rock for the full length of the dam.

The height of the embankment at Mangla has to include a central core of impervious material, a filter zone and pervious fill in the outer portions. An idea of the structure may be had from the quantities of fill which are: impervious core of 10 million m^3 (13 million cu yd) and filter and outer zones of 31 million m^3 (40 million cu yd).

The upstream face of the dam must be protected against wave action, because the fetch is at least 16 km (10 miles). The material to be used would grade in size from quarry sprawls up to pieces 0·6 m (2 ft) in diameter. The downstream face will also require some special treatment to control erosion. This may take the form of a blanket of rock or terracing.

Spillway

Records of the flow of Jhelum river at Mangla are available for the period 1922 to date. During this period there have been two floods in excess of 14,100 m^3/sec (500,000 cu ft/sec), four floods in excess of 8,500 m^3/sec (300,000 cu ft/sec), and flows greater than 4,250 m^3/sec (150,000 cu ft/sec) occured in most years. The maximum flow ever recorded was 21,500 m^3/sec (760,000 cu ft/sec), These data indicate that there is reasonable probability of the occurrence of a flood having a peak discharge as great as 28,300 m^3/sec (one million cu ft/sec).

After routing each major flood through Mangla Reservoir, assuming a spillway of 244 m (800 ft) nett width and fixed crest width of the weir at 337·5 m (1,140 ft) and reservoir full at the beginning of the flood, it has been found that the temporary pondage above elevation 359·1m (1,178 ft) reduced the maximum recorded flood to an outflow of 112,740 m^3/sec (450,000 cu ft/sec) and that the outflow would have exceeded 8,500 m^3/sec (300,000 cu ft/sec) in two years only. A flood flow of 28,310 m^3/sec (100,000 cu ft/sec) of similar characteristics would have produced a discharge through the spillway of about 19,817 m^3/sec (700,000 cu ft/sec). Allowing margin on account of short period of historical records a spillway of 28,310 m^3/sec (100,000 cu ft/sec) with 3·66m (12 ft) surcharge above normal reservoir level has been taken as the basis of design.

Automatic gates having an aggregate length of 224 m (800 ft) and a net effective height of 11·58 m (38 ft) are provided in the design. The cost of these gates would be high, but without them the height of the dam and other embankments for the same reservoir capacity would have to be 9·14 m (30 ft) and the spillway be made several hundred metres wider.

As no chances are to be taken with an embankment type of dam, despite very generous capacity of permanent spillway which can take care of an unregulated flood of about 42,500 m^3/sec (1·5 million cu ft/sec) in Jhelum river, provision has been made for spilling large quantities of water over the southerly rim of the reservoir in case of emergencies.

Diversion and Outlet works

The topography and geology of the site has necessitated to combine diversion and outlet works in the form of tunnels.

The design was governed by several factors :

(a) The outlets must be large enough to enable the entire flow of Jhelum river to be diverted during the period necessary for construction of the dam across the present channel of the river.

(b) They must be suitable for eventual use as pressure tunnels through which water will be carried to the power plant.

(c) Provision must be made for rapid conversion of these tunnels from free discharge outlets to their normal use.

(d) The size of the tunnels must be held down to avoid construction difficulties because of the nature of the rock through which they will be excavated.

Four tunnels of 7·92 m (26 ft) diameter have been found suitable for future power requirements and will be practicable for construction. They will be concrete-lined before the diversion of the river, and steel-lined afterwards to convert them into pressure tunnels. The floor level of the tunnels is, of course, governed by the location of the intake tower and general topography of the alignment.

Coffer dam

All major floods of record and a number of characteristic smaller floods were routed through the four 7·92 m (26 ft) diameter tunnels to determine the elevations to which the crest of the coffer dam and the main embankment would have to be brought progressively to insure against overtopping during construction. These tunnels can carry about 850 m^3/sec (30,000 cu ft/sec) when running full without surcharge. The discharge increases rapidly to about 2,831 m^3/sec (100,000 cu ft/sec) as the head is built up in the reservoir, but very slowly thereafter because of progressively greater losses. Routing the flow through these tunnels showed that historical flows on record could have been diverted in October, November and December, without exceeding the upstream water level of 1950. The floods of January, February and March would not have filled the reservoir above elevation 305 m (1,000 ft) except in one year when there was a flood large enough to require a coffer dam to be up to elevation 314 m (1,030 ft) by the first of March and this height of the coffer dam would have been ample to force all water through the tunnels in April and May of every year and all but once in June. However, more temporary storage would have to be provided to impound flood flows in excess of the diversion capacity during the monsoons in July and August. The height of the coffer dam in each month should

thus be above the anticipated water level behind the coffer dam.

Yield of the Mangla Reservoir

All of the low flow and some of the flood waters of Jhelum river are now used for irrigation through the Upper Jhelum Canal, the Lower Jhelum Canal, the Lower Chenab Canal, etc. The measure of the Mangla Reservoir yield would thus be the extent to which flood flows would be reduced below the last headworks on Indus river of which Jhelum is a tributary.

From the available data it has been found that the use of water originating in Jhelum river is now about 12,335 million m^3 (10 million acre-feet) per year and that remainder of the river flow approximating 16,036 million m^3 (13 million acre-feet) in an average year is wasted during floods which are usually coincident with floods in the other rivers.

Studies to determine the gain in the supply of usable water that would result from regulation of Jhelum river show that if a reservoir of an effective capacity of about 12,355 million m^3 (10 million acre-feet) could be created at Mangla, the entire flow of Jhelum river would be regulated completely in almost every individual year; but more storage would be needed for regulation over periods of several consecutive years. Actually, however, physical conditions limit the effective capacity of Mangla Reservoir to less than 4,934 million m^3 (4 million acre-feet) so that a complete control of Jhelum river is not possible. A reservoir of 4,317 million m^3 (3.5 million acre-feet) effective storage capacity would control a release aggregating 19,736 million m^3 (16 million acre-feet) in every year, but there would be no spill in the period of two consecutive years of dry periods. Similar groups of dry years are to be expected in the future so that controlled releases of water from Mangla Reservoir in amounts greater than 19,736 million m^3 (16 million acre-feet) annually cannot be relied upon for irrigation use and generation of power. The initial gain in the usable supply of water from Jhelum river will thus be 7,401 million m^3 (6 million acre-feet) per year even in the draught periods.

Practically all this supply of water available for expanded irrigation use will be transferred to Chenab river through the Upper Jhelum Canal after its enlargement, and become mingled with the Chenab water. If the area to be developed were served from the Mangla reservoir during the sowing and maturing periods of summer crop only, and for the remaining period of about three months put on the Chenab when surplus supplies are available in it, 3,700 million m^3 (3 million acre-feet) of Chenab surplus can also be made use of by co-ordinated regulation. Thus the indirect yield of the Mangla Dam would be 17,102 million m^3 (9 million acre-feet) which can bring an additional area of 2 million hectare (3 million acres) under irrigation.

Economics

The total estimated cost of the project is Rs 730 million and with devaluation this figure will go up to the extent of the foreign exchange involved. The benefit accruing will be:

(a) 7,400 million m^3 (6 million acre-feet) development of water from Jhelum river and additional 3,700 million m^3 (3 million acre-feet) from the flood flows of Chenab river.

(b) The installed capacity of 300,000 kW (all firm),

(c) Flood control,

(d) Fish culture in the lake,

(e) Health and tourist resort,

(f) Improvement in communications.

The capital cost is proposed to be apportioned to the first three items only. The project will be productive within three years of its commencement. It is, therefore, of a high order of economic feasibility.

Siltation

Jhelum river carries large volumes of silt and sand and other sediments, particularly during the floods caused by monsoon rains. Very little of such sediments will pass through the Mangla Reservoir so that there will be a progressive loss of capacity of the reservoir.

Gauging of the silt contents of Jhelum river was started about two years ago; this period is not long enough to establish the average silt burden, but certain trends are indicated. The over-all average silt burden of Jhelum river is roughly 0·3 per cent by weight of the total quantity of water in the river. Taking an average density of about 1·284 gm/cm^3 (80 lb/cu ft) of sediments an average accumulation of 68 million m^3 (53,000 acre-feet) of suspended sediment per year is probable, and allowing for the unmeasured bed load, would bring this figure up to 74 million m^3 (60,000 acre-feet) per year.

It has been observed at many reservoirs that there is segregation of the sediments carried by the stream. The coarse fractions drop out near the head of the reservoir, the very fine material flows to the lowest portion through the action of density currents. Some of the silt and clay that constitute about one-half of the total sediment load of Jhelum river, will be trapped with the coarser sediments in the deltas, but more of the clay particles and fine silts should reach the floor of the reservoir. The rate of accumulation of these should be 25 million m^3 (20,000 acre-feet) per year. Therefore, 740 million m^3 (0·6 million acre-feet) of dead storage provided initially in the Mangla Reservoir would thus be filled in 30 years.

Deltaic deposits will form near the head of the reservoir and gradually progress downstream, maintaining a fairly constant elevation at the break in slope, along the forward edge of the delta. This will tend to reduce the grade of the river upstream thereby causing deposition of coarse sediments outside the original limits of the reservoir. One arm of Mangla Reservoir extends about 32 km (20 miles) up the canyon of Jhelum river. The original water depth at the mouth of this canyon will be about 60 m (200 ft). Hence, by the time the front of delta reaches this point, the sediments

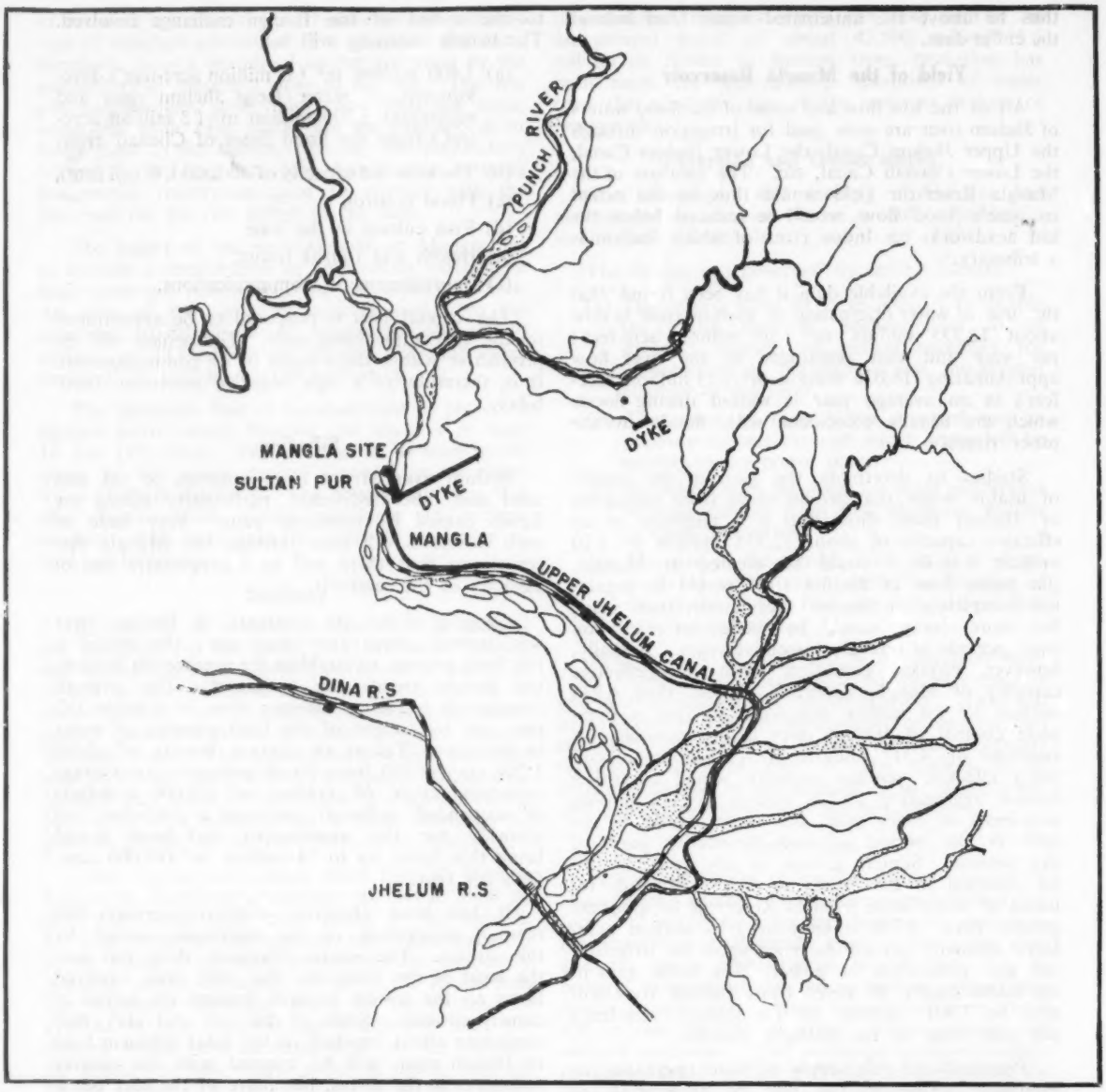


Fig. 1—Index Map of Mangla Dam Project

at the original upper end of the reservoir would have to be 60 m (200 ft) deep in order to maintain the same slope of the river. A somewhat similar, but less pronounced condition, exists in the Poonch river arm of the reservoir. It is, therefore, probable that at least half the coarse sediments will come to rest along the channels of these streams outside the limits of the Mangla Reservoir. This situation has been observed accurately in the case of Elephant Butte Reservoir in the United States, where the rate of loss of capacity is now less than one-half of the silt burden of Rio Grande.

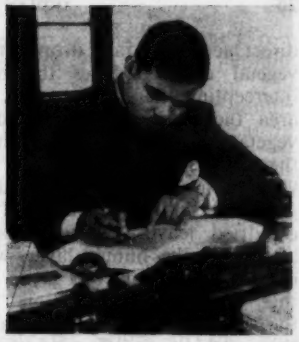
It is, therefore, believed that the loss in effective capacity of the Mangla Reservoir will not be greater than 24.67 million m^3 (20,000 acre-ft) per year during the first 30 years of operation, nor more than 49·34 million m^3 (40,000 acre-feet) per year thereafter.

The life of the Mangla Reservoir would thus be between 100 to 150 years. The life can be increased by silt-check dams upstream or the protection of the catchment area with afforestation and other methods.

The cost of the Mangla Dam Project is proposed to be amortised in 50 years so that the invested capital would be available for a replacement dam before its entire life is extinguished.

(From *Flood Control Journal*, UN-ECAFE)

Silt in Relation to Irrigation and Power Projects



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ONE of the greatest dangers which threatens the effective life span of most of our costly irrigation projects is the gradual silting up of the bed of the reservoirs and canals. In view of peculiar conditions of rain fall in our country where the bulk of rain falls within approximately four months of a year and is mainly orographic in nature, the danger of silting up of our reservoirs and canals becomes all the more paramount as the rushing rain water emerges from the hills heavily loaded with silt which gets deposited when the rivers enter the plains. It needs no repetition here that this danger of silting up is being voiced since long ago, but it is rather unfortunate that no concrete steps appear to have been taken so far to tackle this problem *a priori*.

To appreciate the appalling danger likely to be perpetrated by the silt, it will not be out of place to go in some detail about the genesis of silt and its deposition. As is wellknown, silt refers to that component of soil which in its physical properties behaves midway between the sand and clay. However, for purposes of discussion in the present paper, the silt may be considered to include the other two components as well. The ultimate source of the silt is the rock from which through the destructive physical and chemical activities of weathering followed or accompained by constructive biological forces, the soil is built up. The controlling factors in the development of soil are climate and vegetation. Geologic materials including mantle rock and bed rock are nccessary but are passive rather than active elements in soil formation. Soil formation is a natural and continuous process and will go on for ever. In the study of silt in relation to irrigation projects, we have to proceed from this basic assumption that additional quantity of silt is being produced every year in the process of soil formation.

So long as the soil remains bound together with the fine roots of vegetative cover there is practically no movement of silt. But the moment vegetative cover is removed, and the soil is exposed to rain and wind, the loss of silt begins. Topography of the area and intensity of the rain determine to a great extent the rate of loss of silt from the place of its formation. In the Himalayan region where most of the areas consist of precipitous and cut-up terrain and where the rain comes in the form of downpour, the loss of silt from barren areas is tremendous. It is said that the loss of soil in the Ganga is eight times that of the Mississipi. In the absence of vegitation over the hilly regions, the rain water rushes through and goes on gaining in velocity till it reaches the main streams. What part velocity plays in removing and transporting silt will be evident from the fact that erosion varies as the square and transport of eroded material as the sixth power of velocity. Thus if velocity is increased to ten times, the erosion and material transported will increase to a hundred and million times respectively. When streams and rivers debouch in the plains after leaving the hills, their velocity is suddenly decreased and the reverse process of deposition of the detritus follows which takes place throughout the length of the river, the finest particle of soil being deposited in the delta of the river. Due to deposition of silt, the river bed is raised which decreases the slope with the result that velocity is further diminished. Thus it almost proceeds in a geometrical progression and very soon the river is forced to cut new lands for its course. This is what is happening in Kosi every year.

Thus the crux of the problem is the transport of silt and its subsequent deposition through the action of rain water. As we have observed earlier we have practically no control over the annual production of silt—its formation being a geological phenomenon. So is true about rainfall. Thus the silt and its vehicle, the rain water are more or less a constant feature beyond our control save to a very limited extent. Now then how to lessen the scourge of the silt. It is one or more of the following ways in which it can be accomplished :

(i) By prevention of silt from erosion at the place of its formation.

(ii) By reducing the silt-carrying capacity of water.

Prevention of silt from erosion

Erosion of the silt as also of other soil component is mainly due to loss of vegetative cover, the roots of which keep the soil particle bound and the layers of leaf mould and the humus which develop from the biological activity of vegetative cover and the vegetative cover itself prevent the

direct action of rain drops on the soil. Thus the vegetal cover reduces the impact of rain drop by intercepting the falling rain. In a well wooded area the rain drops first touch the upper layer of vegetation where their velocity is broken and then they pass gradually through the middle layer of vegetation and then reach the ground layer. The ground layer in such an area consists of a layer of dried leaves, twigs, and a host of ground flora and lastly the humus layer, which may be 1′ to 2′ deep. It is below this layer that the soil lies in the warmth of vegetation. The rain drops reach the soil after passing through this layer. Due to this cushioning effect of the ground layer, practically no silt is lost due to the direct action of the rain. As against this the behaviour of rainfall over an area which is bereft of vegetation is quiet different. In bare area each rain drop falls with the force of a hammer, puddles the top and fine soil and ultimately sweeps it away with ever increasing power of erosion. There is practically no chance for the silt to remain for any considerable period over the bare areas. The following data collected after a single heavy storm will tell the truth of it :

Nature of Cover	*Loss of soil*	*Loss of Water*
Forest	1	1
Grass.	27	32
Bare land	125	800

It will be thus evident that if we want to prevent the excessive and abnormal erosion of silt from its place of formation, it is *sine-qua-non* to maintain a thick vegetative cover. This is particularly important in regions of higher rainfall, such as the middle and outer Himalayan regions.

Reducing the silt carrying capacity of the running water

Running rain water is the real vehicle of silt. If some how we could regulate it, we would have achieved our object. We have observed earlier that we have practically no control over the quantum of rainfall which occurs annually in our country. As it is, the quantity of rainfall is far too great in most parts of our country. The distribution of the rainfall both over time and space is so faulty that most of the rain falls in a limited period of about four months in a year over a limited space mainly in the central and the eastern Himalayan region. In this region the average rainfall per annum may well exceed 200 inches. A closer study reveals that the zone of maximum precipitation in the outer Himalayan range constitutes the region situated between 3000′ elevation to 6000′ elevation. Most of this rainfall has to be drained away to sea as it far exceeds the amount which can be absorbed and detained as ground water. All that man can do is to regulate the flow of this excess water so that as little as possible silt may be carried with the water. The regulation of this excess flow can be best promoted by impeding the velocity of the excess rain water over the catchment area and hastening its velocity in the plains. The velocity can by effectively impeded by putting obstruction on the way of the rushing rain water. This can be achieved by artificial dams all over the catchment area at the sources of the innumerable *nallas* and streamlets and at the junction of two or more streams. But those who have seen Himalayas, its vastness and its ups and downs and the fury of the monsoonic rain over it, will agree that it will be an utopia to think of arresting the velocity of the rushing rain water by dams and revetments in the bare, cut-up and precipitous Himalayas. Observation confirms that the solution of stone and mortar is just impossible to carry out save on a limited scale. That the presence of a good vegetation cover consisting of trees, bushes and grasses on the way of rushing rain water will definitely arrest the velocity, will be self-evident to those who have studied the behaviour of rainfall over wooded areas and over bare areas in the hills. Each tree acts as a veritable dam. In the presence of the vegetation cover, the excess rain water will be drained in longer duration so that the quantum of excess rain water will be much less at a time, resulting in very little carriage of silt.

The author of this note had the opportunity of observing in detail the behaviour of torrential monsoonic rainfall over a part of mountainous catchment area of Ganges in district Garhwal, Uttar Pradesh, for about four years. Here, there are two contrasting areas present side by side. On the one hand there is an area of more than 100 sq. miles of the middle and outer Himalayan ridges which is bereft of any vegetation, as the same has been destroyed in the wake of bringing more land under plough. On the other hand there is approximately the same extent of area adjoining the above one which is Reserved Forests managed by the Forest Department, Uttar Pradesh. The average rainfall of this region is approximately 80 inches per year. In the first instance it is noticed that in the region where the vegetation has been destroyed, the ridges ranging from 2,000′ to 6,000′ in height are cut-up into numerous *nallas* whereas in the ridges covered with forests there are only few *nallas* and streams. When it rains heavily then it is noticed that muddy water loaded with silt gushes through the innumerable *nallas* and streams with great velocity eroding and cutting the hillside and within less than a a week of the cessation of the rains the *nallas* become practically dry. In comparison to this in the few *nallas* and streams which originate in the forests even after a heavy rain, the water comes out in a much cleaner condition and remains flowing for months. The Central Water & Power Commission of India will be well adviced to lay out a hydrological experiment over such contrasting areas to confirm the above observational evidence.

The fear that raising of forests over the catchment areas may give rise to such questions as whether it is possible to afforest snow clad hills or whether it would be possible for us on economic grounds to let the forest wealth go untapped from generation to generation, or to ban grazing at the expense of our cattle wealth, does not stand to reason. The following account will show that this is not correct.

The snow clad hills do not come in the picture so far as regulation of excess rain water in our rivers is concerned. By the time monsoon reaches there,

most of its moisture has been precipitated. The rainfall is much less towards the inner Himalayas where snow clad hills lie, and that too most of it may be in the form of snow. There is absolutely no necessity, nor is it possible, to afforest the snow clad hills. So far as the carriage of silt in the rivers of Northern India is concerned, the catchment areas up to approximately 10,000 feet elevation which extend over the outer and middle Himalayan ridges really matter, more particularly the middle region between 3000 to 6000 feet. Above this elevation (10,000 feet) there is hardly any habitation and most of it is covered with natural vegetation upto the limit of vegetation which is anything from 12,000 feet to 14,000 feet depending on aspect. It must be fully understood that when we talk of afforestation we mean afforestation in the bare, treeless outer and middle Himalayan ridges and not in the snow clad hills.

Similarly to say whether it would be possible for us on economic grounds to let the forest wealth go untapped from generation to generation as a consequence of resorting to regulation of excess rain water by preserving vegetation over the catchment area, is not correct. In fact, the obverse is true. If we preserve more forests, we shall get more forest produce out of them. The vegetation is an organic entity; it grows, and reproduces itself. Every forester knows that by scientific management without impairing the hydrological role of the forests, quite a considerable quantity of the forest produce may be extracted from the forests. There is, therefore, no question of allowing the forest wealth to go untapped from generation to generation. In fact, in extensive afforestation of the hilly, mountainous and undulating catchment areas lies the solution of the balanced economy of not only the hills but of the plains too.

The same is true about cattle grazing. Grazing in itself is not a curse for the vegetation. It is unregulated and over-grazing which is harmful in the establishment and maintenance of effective vegetation cover. Depending on the characteristics of the vegetation, a minimum number of animals can always be allowed to graze without any harm to the vegetation. In fact, by regulating the grazing, we shall be adding to our cattle wealth. The question of banning the grazing does not arise.

Contour bunding of the hilly catchment areas will no doubt lessen the velocity of rushing rain water, and thereby reduce the carriage of silt but as pointed out by an expert, its cost will run into thousand crores. For the bunding of Kosi catchment area alone we might need 160 crores of rupees. But do we need to contour bund the entire catchment area of a river system ? Certainly not. Besides being staggeringly expensive and impracticable, it will be only temporary. Most of the contour bunds are likely to give way to the first onslaught of monsoon. The solution of arresting the velocity of the rushing rain water in the hilly catchment area, therefore, does not lie in contour bunding. Contour bunding may help us in moderately sloping areas where rainfall is not very heavy and does not come in downpours. In the hilly catchment areas which extend from Western Uttar Pradesh to Assam, the rainfall is so heavy—it is anything from 80″ in the Western Himalayas to 300″ in Assam per annum and may be several inches in an hour—that the only thing which can check its velocity will be the vegetation in the form of forests. Of course whatever cultivation exists in the hills must be carried out in terraces not only to give better stability to the field themselves, but also to prevent soil erosion of the top soil, rapid run-off of the excess rain water which will ultimately help in reducing the intensity of silt load of the rushing water. Cultivation along the slopes of the hills without terracing must be banned altogether.

It has been argued 'that the geological crumbling process of rocks is augmented by growth of trees, along the roots of which the rain water travels to greater depths in rocks. When earthquakes occur, mighty trees root out and all crash along with crumbled rocks. The soil cover and hill sides crack up and fall, and the detritus and humus is flooded down to the plains during the monsoons'. No one denies that vegetation over the hills augments the geological crumbling of rocks. But it must be borne in mind that it is a geological process and takes place in a geological scale of time. It is said an ounce of soil is produced from the interaction of rock and vegetation in approximately a thousand years. Indeed, it is due to this geological process that we have such fertile plains. We might say that as a result of this process the area of plains may extend upto the present site of the Badrinath shrine in a million years. This geological consequence of forests is insignificant for the solution of our immediate problem. On the other hand, in the absence of vegetation in the catchment area, without any earthquake, only after a heavy shower of rain, the rain water emerges as a rushing torrent with an ever increasing velocity, breaks pieces of rocks by sheer physical force, carries detritus, top soil, humus and whatever comes in its way to the river which in its turn transports them down below, settling the detritus in its bed gradually as its velocity decreases—heavier first and lighter afterwards. Rushing torrents charged with angular stones erode hillsides in an ever increasing vicious circle. Nothing will be more efficacious to check the velocity than a good vegetation cover over the catchment area.

There is no doubt that occurrence of earthquake —which God may forbid — might lead to hillsides cracking up and trees, soil cover and a mass of detritus choking up the rivers and causing floods. But the pertinent question is — will any structure of brick and mortar, be it a dam, reservoir or embankment raised to regulate the excess rain water withstand the onslaught of earthquakes better ? Before the trees would have touched the ground and crack widened in the hillside, masonry structures for regulation of excess rain water will be nowhere, and may spell disaster of unknown magnitude. This is, therefore, no argument against the effective role of vegetation in reducing the velocity of excess rain water.

However, it must be admitted that forests are essentially a long term remedy in regulating the flow of excess rain water. For immediate relief the importance and necessity of engineering devices such as embankments, reservoirs, parallel channels cannot be denied. But in a country like ours where the heaviest precipitation is orographic on the outer slopes of Assam hills and outer Himalayas and may exceed 200 inches per annum and then most of it falling during a period of hardly four months viz. beginning of June to the end of September, the role of vegetation of the catchment area in the regulation of flow of excess water must be considered most paramount. Higher levees, banks set farther back from the channel, dams, impounding of large tributaries, parallel channels, etc. will not survive the onslaught in the long run of the tremendous volume of water that will rush from the catchment area in the absence of vegetation. Besides, in the absence of vegetation cover over the catchment area there is a great risk of the river bed, dams, parallel channels, etc. being silted up and becoming ineffective.

In China the commonest method of regulation of excess flow of water so as to prevent the occurrence of floods particularly in Hwangho and Yangtse rivers had been the building of embankments and levees along the low land course of the river. The Chinese have been using it for more than four thousand years. The great Yu, founder of the Hsia Dynasty, who began to reign about 2205 B.C. put in hand a system of regulation of flow of excess water. His plan was the deepening of the river channels and the building of dykes. The latter method has been followed right up to the present time, but the former sadly neglected. The result is that bottom of the Hwangho is in many places forty feet above the level of the surrounding country. In the floods of 1931 the Yangtse rose on fifty feet above its normal level, broke through scores of miles of dykes flooding to a considerable depth thousands of square miles of thickly populated country. The country being for the most part flat, the water poured over the land like a raging torrent fifteen and twenty feet high in places, destroying virtually everything in its track houses, livestock, crops and implements. Hundreds of towns and villages were completely destroyed. It is estimated 150 thousand people perished.

This has happened in China where rainfall conditions are of much less magnitude than what they are in our country. In China the maximum rainfall nowhere exceeds eighty inches in a year and that too is fairly well distributed both in respect of time and space. It may be made possible in our country too to regulate the flow of water temporarily by raising high embankments set farther apart on both sides of a river or by providing retention reservoirs but if no attention is paid to the catchment area, by gradual silting up our rivers may start behaving the China way in course of time, not very distant in future. The conclusion is, therefore, irresistible that for permanent control of the silting up the vegetation cover over the catchment area is a *sine qua non*. If the afforestation of the catchment area cannot precede the building up of dams, embankments, etc. it must go at least hand in hand.

Thus having established that the *raison de etre* of silting up in the river beds in reservoirs is the absence of proper vegetation cover over the catchment areas, the following concrete steps are suggested :—

(1) *Preservation of the existing forest growth over the Himalayan ridges and other catchment areas :*

Exact data as to how much of the existing forests over catchment areas of Ganges, Kosi and the Brahmaputra with their tributaries are still not under proper scientific management will have to be collected. From what is known of Uttar Pradesh, only a fraction of the forests are under Forest Department and some forests under village Panchayats which are well managed. But by far the largest forest areas are classified as Class I forests which are managed by civil authorities by no means on scientific lines. It is imperative that with immediate effect all such forests should be put under the control of the Forest Department for scientific management. One of the cheapest and best methods of not only preserving but materially augmenting the existing denuded forests over the catchment areas will be to fireprotect them and close them against unregulated grazing and lopping. Needless to emphasize that if the areas are left to themselves without the interference of the man, Great Nature will do its duty and quite a large proportion of the denuded forests will recover and form a real soil cover within a decade. The interests of only a few million of people who live in the hills must be subordinated to the larger interest of the community which inhabit the plains. People in the hills should be convinced by means of proper education and propaganda that in the preservation of the forest over the catchment areas in the hills, lies not only the security of the millions of people residing in the plains, but there lies the welfare of these people too. For, what is happening in the hills these days — at least so is true in Kumaon and Garhwal Hills of Uttar Pradesh with the indiscriminate cutting of forests, the flow of water in the streams is getting less and less with the result that many villages are faced with the problem of water during summer in so acute a form that they have to leave their hearth and home in quest of water. Due to lack of irrigation the yield of crops per acre goes down. The cultivator tries to make up the yield by bringing under cultivation more land by cutting the nearby forests. Thus a vicious circle has been created with the result that the hillman is being driven to more poverty and misery apart from what doom and destruction his ruinous action bring to the plains. We, therefore, must approach the hill people in a real and earnest way and must obtain their co-operation in this great and noble task. With their active co-operation our task will be made much easier.

(2) *Reforestation of the treeless and bare Himalayan ridges :*

An immediate survey of the treeless regions of Himalayan ridges which constitute the catchment areas of the Ganges, Ghagra, Kosi, Brahmaputra and their tributaries should be undertaken. A proper machinery to tackle the afforestation of these areas should be constituted without any further delay. An extensive scheme of afforestation will not only go to control the floods but will give employment to local people and raise their income. It is expected that some proportion of such areas will be Government land. Even wherever they belong to people, they should be pursuaded in their own interest to get such areas reforested through the agency of the Afforestation Department. We should even go to the extent of agreeing that they will be the owner of half of the income of the forests which will accrue in due course. With proper approach people will willingly give their otherwise unproductive land for afforestation.

(3) *Afforestation in plains on ravine lands, banks of ravines and streams, etc.*

In order to prevent silting up of the local *nallas*, streams and rivulets so as to maintain their better drainage capacity, it is essential to resort to all possible soil conservation measures. Afforestation work should be extended on all the ravine lands, waste lands, banks of streams, etc. Planting of such harmless but exceedingly useful tree as *Babool* should be encouraged on the borders of agricultural fields. Here the unwary might argue that the presence of trees in the plains area will impede the effective drainage of the excess rain water. We must appreciate that flood (precursor of silt) is always caused by the overflowing of rivers, streams and *nallas;* we must, therefore, endeavour to maintain their drainage capacity to the maximum which can only be achieved if we prevent their bed from silting up which is possible through the presence of a good vegetation cover in the forms of trees, bushes and other plants which keep the soil bound. It is true that the tree will appear to put obstruction in the flowing of local rain water, but due to better drainage capacity of the adjoining nallas, of streams and of rivers which will result from the surrounding vegetation, the draining of excess water will be much quicker, harmless and effective. Besides, additional afforestation will meet the local requirement of fuel and will release cowdung to fields and raise the food production by at least 10%. It may be noted that cowdung manure is *par excellence* but at present due to shortage of fuel it is the principal source of fuel to the villagers. Plantation along the banks of rivers will tend to make natural embankment in course of time.

(4) *Afforestation in the catchment areas of dams and reservoirs :*

Whenever it is proposed to construct a dam or a reservoir, the work of afforestation of its entire catchment area on scientific lines must be taken up in hand at once. The ideal scheme would be to completely establish the vegetation over the catchment area by the time the project is commissioned. This aspect of irrigation project must be made a part and parcel of every river valley project. This will not only solve the problem of silting up, but will raise a national wealth of great value. To every major project at least one afforestation circle should be attached from the very beginning.

(5) *Management of the forests on an all India basis :*

We cannot deny that any forest which is now thought to be necessary or worth preserving will be held to be so for all time, but the facilities for destruction of forests are so great, the difficulty of reproducing them so insurmountable and the general tendency in this country to accept as truth the fallacy that the clearance of forest is of itself necessarily an improvement so common that it will require a strong, capable and pursuasive machinery to protect the existing forests. Besides, the vegetal rehabilitation of the maltreated catchment area is so widespread and imperative not only in controlling the deposition of silt but in ameliorating the economic condition of the people in other spheres that a bold programme under the Central Government needs to be launched immediately. In order to attract better talents for administering the forests scientifically, the revival of All India Forest Services deserves serious consideration.

(6) *Training of rivers and streams :*

In order that the rivers and streams may flow in regular channel, wherever necessary their currents should be trained by construction of spurs, deepening their channel mechanically etc. after the rivers have left the hills.

To sum up, the scourge of silting up can be reduced to a great extent — if not controlled almost permanently, in a decade or two, if a correct synthesis of the forest plan and engineering devices is taken up in right earnest. Resorting to latter without consideration of the former will mean postponing the evil for a later date and is doomed to failure. Arousing people's consciousness towards the general benefit of the vegetation and a correct appreciation of its role in prevention of silting up and in flood control in particular, together with Government's efforts in preserving the existing forests, afforesting the denuded catchment area of river system are bound to bear fruit.

Notes & News

Hydro-Electric Resources of Asian Countries

A meeting of the Working Party of the ECAFE held in July, 1957, has recommended an early overall assessment of hydro-electric resources of Asian countries, and has suggested methods to be used for gauging four categories of hydro-electric potential, namely, theoretical protential, technically feasible potential, economically feasible potential and potential of presently installed capacity.

In the eleven recommendations made by the working party, the countries of the ECAFE region are asked, first to formulate a policy for exploitation of their power to be utilised from various sources both in the long-range and for their short-term needs. It is also recommended that they should determine a programme for investigating their resources, and funds should be allocated for this purpose. This would result in vast economies through a selection of more economical projects appropriate to the needs. Hydrological and topographical investigations should be conducted by a specially set up organisation with appropriate equipment and personnel.

In its general observations the ECAFE working party notes that several Asian countries are short of specialists for making investigations, and it suggests that they should try to secure external assistance, either through the UN Technical Assistance Administration or through other aid programmes.

Countries represented at the meeting were: Burma, Cambodia, Ceylon, China, Indonesia, Japan, Laos, New Zealand, the Philippines, Thailand, USSR, USA, Malaya and British Borneo.

State Electricity Boards

The Government of India in the Ministry of Irrigation and Power have by a notification extended the time upto 30th September, 1957, within which the States of Andhra, Assam, Bihar, Mysore, Orissa, Punjab and Uttar Pradesh are to form the Electricity Boards.

Rajasthan Electricity Board

The Government of Rajasthan have by a notification constituted the Rajasthan State Electricity Board comprising of Shri K. P. U. Menon, I.A.S., former Commissioner, Kotah Division (as whole-time Chairman); Shri Ganga Sahai Purohit, I.A.S., Finance Secretary to Government as ex-officio Finance and Accounts Member; Shri Bashir Ahmed Khan, Deputy Chief Engineer, Electrical and Mechanical Department as ex-officio Member for a period of two months. The Government is negotiating for a Senior Engineer to take over as Chief Engineer in this State. As soon as he joins his duties, he shall be appointed as Engineer Member in the Board. Shri B. D. Somani, Industrialist of Bombay as part-time Member; Shri Thakur Madan Singh, of Nawalgarh, Jaipur.

Madras State Electricity Board

The Government of Madras have by a notification constituted with effect from 1st July, 1957, the Madras State Electricity Board.

Chairman—Mr. S. K. Chettur, I. C. S., Secretary to Government, Public Works Department.

Ex-officio members—Sri V. P. Appadurai, B.A., M. I. E. (Ind), Chief Engineer (Electricity), Sri T. A. Varghese, I. C. S., Secretary to Government Finance Department, Sri T. K. Palaniappan, I. A. S., Director of Industries & Commerce, and an Accounts member to be appointed.

Targets for Heavy Electrical Goods

During question hours at the last Session of the Parliament, it was indicated that the Planning Commission have approved revised targets for Heavy Electrical Industries as follows during the Second Five Year Plan.

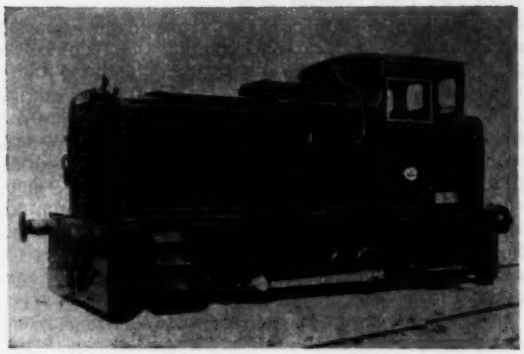
Industry	*Original target*	*Revised target*
1. *Electric transformers* (33 kV and below) ..	1.5 million kVA	2.2 million kVA
2. *Electric motors* (200 H.P. and below) ..	600,000 H.P.	1.25 million H.P.
3. *Electric Cables and Wires*		
(*i*) A.C.S.R. Conductors ...	21,570 tons	30,000 tons
(*ii*) VIR & PVC Cables ...	334 million yds.	500-600 million yds.
(*iii*) Paper insulated power cables ...	784 miles	1,800 miles
4. *Switch gear and Control gear*		
(*i*) Iron clad switches and switch-fuse units ...	800,000 numbers	
(*ii*) LT Oil/Air circuit breakers ...	3,500 ,,	
(*iii*) Motor control gear ...	120,000 ,,	
(*iv*) 11 kV Switchgear ...	1,600 ,,	

The targets are based on the recommendations of the Development Council for Heavy Electrical Industries.

(*Continued on page 32*)

A New Diesel Hydraulic Locomotive

The Diesel hydraulic locomotive is now well established and several types are in operation using hydraulic torque converters of various designs. A new type, the principal features of which is its symplicity, has been introduced by Messrs. Andrew Barclay, Sons & Co. Ltd., of Kilmarnock, for whom, Parry & Co. Ltd., are Agents in India. This locomotive is fitted up with a British Twin Disc torque converter, the first to be applied to a locomotive in this country.



The locomotive is of the 0-4-0 type and is fitted with a National five cylinder diesel engine developing a maximum of 200 B.H.P. at 1500 r.p.m. The locomotive is intended for shunting duties and for this class of work, the most desirable characteristic is a high tractive effort for starting combined with a steady pull to minimise wheel slip and with the possibility of accelerating steadily up to a moderate speed.

Most diesel hydraulic transmissions have hitherto embodied two or more converters or a converter and fluid coupling or a converter and change speed gearbox in order to provide a sufficient range of torque variation but the British Twin Disc three-stage torque converter is capable of giving a maximum range of 5 or 6 to 1 and can therefore be used as a single unit in a shunting locomotive. The operation of the converter is entirely automatic, depending on the speed of the input and output shafts. Actually the full range of 5 or 6 to 1 torque multiplication is not used as the efficiency is low when the multiplication is as high as this but part of the range is used giving a torque multiplication of approximately 4 to 1. This is equivalent to that obtainable from a normal 4-speed gearbox. This wide range is not obtained from any serious loss of efficiency, the efficiency of the converter being 70% at each end of this range and at its best speed the efficiency rises to a maximum of 82%. It is possible to fit the tractive effort of the locomotive exactly to that called for by the load and to utilise the full power of the engine at all times. This is not always possible with a change speed gearbox as the tractive effort required by the

(Continued overleaf)

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(Continued from previous page)
conditions may not be exactly obtainable without adopting a lower gear and running the locomotive at a lower speed than might otherwise be obtainable. The smooth variation in the tractive effort of a hydraulic locomotive ensures that there is no jerking of the transmission or train such as occurs when changing gear on a diesel mechanical locomotive. This is of particular importance when working with loose coupled rolling stock. Compared with a two or three stage hydraulic transmission, there is no governor or arrangement of valves to control the change-over from one stage to the other. In addition to this, there is no free wheel.

The application of power when starting from rest is perfectly smooth and the locomotive can therefore be of the minimum weight to give the maximum tractive effort. The maximum tractive effort of this locomotive is 20,000 lbs. It is 18,000 lbs. at 2.4 m.p.h. and 4,500 lbs. at 9.6 m.p.h., this being the range of speed in which the efficiency of the converter is 70% or over. The weight of the locomotive is 31 tons giving an adhesion ratio of 3.5 to one with the 20,000 lbs. tractive effort. The locomotive will run up to a maximum speed of 11 m.p.h.

The engine is of the National M4AA5 type having five cylinders 6" bore by 8½" stroke. It is set to develop a maximum of 200 B.H.P. at 1500 r.p.m., this being a 12-hour rating. It is of advance design and incorporates four-valve cylinder heads with controlled turbulence resulting in high thermal efficiency with good combustion at all loads. Solid injection into an open combustion chamber is used. Starting is by electric motor engaging with a toothed ring on the flywheel.

Electric lighting is provided on the locomotive consisting of head and tail lamps, a cab lamp, lamp under the engine casing, two lamps over the instrument panel and a portable inspection lamp. These are supplied from the starting batteries which are of ample capacity.

The mechanical construction of the locomotive is extremely simple. The Twin Disc torque converter is rigidly mounted on the engine crankcase, in addition to which it is supported at the output end from one of the locomotive frame stays. From the output shaft of the torque converter the drive is taken by a propeller shaft with Layrub flexible couplings at each end and the drive is taken from these to the rail wheels by means of connecting and coupling rods. The reverse gear is of the bevel type consisting of a bevel pinion running between two crown wheels which are mounted on roller bearings on a cross shaft. Either of these crown wheels can be connected to the cross shaft by means of a multiple toothed clutch which slides between them on splines on the shaft. From this cross shaft the drive is taken by means of double reduction spur gears to the jackshaft. All shafts in the reverse and final drive unit including the jackshaft are mounted on roller bearings. The casing of the gearbox is of cast iron and is bolted to the frame by fitted bolts so that in addition to forming a rigid mounting for the jackshaft, it acts as an effective frame stay. It is possible to dismantle the gearbox and remove all shafts including the jackshaft without disconnecting the principal casting from the frames of the locomotive.

A friction clutch is embodied in the torque converter casing between the engine and the torque converter. This clutch is only fitted to provide a free engine when the locomotive is standing and to facilitate operation of the reverse gear. It is of the over-centre type and is therefore either fully engaged or disengaged. It is not used for taking up a load and the wear on it is consequently negligible. It must be engaged to connect the engine to the torque converter and must be disengaged momentarily to eliminate the drage torque of the converter to allow the reverse gear clutch to be moved. It is operated by a hand lever and requires very little effort. An interlock of the simple mechanical type is provided to prevent the reverse gear handle being moved unless the clutch is disengaged.

Another interlock, patented by Messrs. Barclay, is also provided to prevent the reverse gear handle being moved unless the locomotive is stationary. This is operated by the flow of oil circulating in the final drive gearbox. So long as the locomotive is moving, and consequently the oil is circulating, a plunger is held up to intercept a sector on the reversing handle shaft, so that it cannot be moved. When the locomotive stops and the oil flow ceases, this plunger recedes and the reverse gear handle can be moved, provided at the same time the clutch is disengaged.

The frames are exceptionally rigid being 1½" thick and are built up with frame stays bolted to them with turned driven bolts. The engine and torque converter are mounted on a rigid sub-frame. The buffer beams are steel 6" thick to provide the necessary weight for adhesion.

The driving of the locomotive is simplicity itself. To start, after the engine is running, it is only necessary to engage the clutch and gradually open the throttle. The engine will speed up and the torque converter will take up the load and it will start with perfect smoothness. If the throttle is fully opened, the speed will rise to the maximum which the power of the engine and the weight of the train will permit and the locomotive will run at this speed indefinitely without overheating of the torque converter, provided the load is within the maximum capacity of the locomotive. It should be noted that it is impossible to stall the engine by overloading the locomotive or by mishandling. The only controls which the driver needs to operate are the throttle, brake, reversing handle and clutch. As in all diesel locomotives, except the diesel electric type, it is necessary to bring the locomotives to a standstill before the reverse gear is changed. As explained above, a patented interlock is fitted to ensure that this is done.

It has been the aim of Andrew Barclay, Sons & Co. Ltd., to produce the simplest possible form of diesel shunting locomotive, both in construction and handling. This aim has been very successfully accomplished in this prototype locomotive, which has already undergone successful tests. It is the forerunner of a range of similar locomotives with powers up to 400 H. P. and the company has already received orders for locomotives of 302 H. P. with British Twin Disc torque converters.

Utilisation of Irrigation Facilities

IT IS wellknown that one of the greatest impediments to a successful execution of the Second Five Year Plan is the slow development of food production in the country. The First Plan, as well as the Second, gave a great deal of emphasis on irrigation and river valley projects. To what extent these large capital outlays are bearing fruit need to be investigated. The Planning Commission has recently published its review of the First Five Year Plan. A study of this document indicates that there is much to be desired in the matter of overcoming the time lag between the completion of the various river valley projects and the actual utilisation of the irrigation facilities offered by them.

Taking the country as a whole the target for availability of additional irrigation from major and medium works in the Plan was 8.5 million acres. The actual achievement at the end of the Plan was of the order of 6.3 million acres while 4 million acres were actually brought under irrigation. The following table gives a breakdown for some of the important States.

Irrigation in First Plan

States	*Target (in lakh acres)*	*Actual irrigation (in lakh acres)*
Madras	4.35	2.21
Madhya Pradesh	1.14	0.1
Punjab	6.66	4.66
Saurashtra	1.297	0.56
Uttar Pradesh	16.75	7.4
West Bengal	3.50	2.23

Discussing the various reasons for this lag between the target and actual utilization, the Planning Commission lists the following factors:

(1) Delay in canal construction,
(2) Shortage of trained personnel and equipment,
(3) Inadequate organisation of the State irrigation departments,
(4) Failure to carry out the necessary land reclamation measures, and
(5) Failure in educating the cultivators in wet farming.

Each of these causes should have been easily anticipitated in a country which has a long tradition of modern irrigation practices. Further, planning loses all significance if it is not related with the efforts of various specialised groups all along the line in order to get maximum end-result. For this purpose it is not necessary to have a rigid and over-centralised organisation throughout the country. But what demands greater attention is to have an imaginative plan to educate the cultivators in terms of the irrigation facitities that are offered to them and to execute this plan simultaneously with the execution of the engineering ones. This aspect of planned endeavour should not prove difficult in the context of democracy and the enlightened self-interest of the agriculturists. We, therefore, think that apart from the technical deficiencies in planning and execution, the fault lies mainly on the political leadership of the country which is the actual lever by which the peasants could be enthused and activised. The members of the Parliament and the State Legislatures have yet to play their due role in this field. In a way it is good to know that the Parliament has taken serious note of the utilisation aspect of irrigation and an investigation into it has been promised.

The Food Grains Inquiry Committee which was presided over by Sri Asoke Mehta has also pointed out in its report that if double-cropping were practised in the areas benefited by the DVC and the Mayurakshi canals, more agricultural prodution could have resulted. This needs education of the agriculturists in new crop patterns and farm practices. It should have been one of the important tasks of Community Project workers and local public leaders to help the farmers to help themselves. But it appears to us that work at the grassroots is neglected, for it does not satisfy our publicity-conscious leadership at all levels.

Sectional Meeting of the World Power Conference

The 11th Sectional Meeting of the World Power Conference held recently at Belgrade quite befittingly concentrated its deliberations on the subject of the development of power in under-developed countries. The experience of highly industrialised countries was placed in the context of the background of problems which the under-developed countries are facing. In the beginning of the discussion it could be easily seen that the two sets of experiences were so different that it was difficult for the delegates representing two different backgrounds to understand each other. But slowly as the discussion proceeded, awareness and understanding became easier.

While the under-developed areas want to develop rapidly and compete with the more industrialised areas, they could do so not only by adopting new institutional devices and financial and economic criteria, but they have also to take full help and co-operation from the industrialised sector of the world. In this, naturally, the industrialised countries would also benefit, thus promoting a general trend towards industrial advancement. The Meeting thus proved to be of great educative value in the sense that whlie representatives from under-developed countries could pinpoint their exact problems and formulate the "don'ts" in their policy, those from the industralised countries would now know better the nature of the situation in the under-developed areas and would adapt themselves in a more practical manner for promoting cooperation and collaboration between the two.

(*Continued from page 30*)

Abstracts

Assessing Bombay's Irrigation and Power Potential

The Government of Bombay has constituted a Water Resources Investigation Circle for a comprehensive basinwise appraisal of the utilisable water resources available for irrigation and hydro-power production in the State.

The Circle consists of five divisions and 22 sub-divisions, with a Superintending Engineer, with headquarters at Bombay, to be in overall charge of the unit. Besides, each division and sub-division has a complement of technical, supervisory and clerical staff to assist the Superintending Engineer in the investigation work of the unit.

A separate division, with four sub-divisions, is to look after the investigation of utilisable water resources for hydro-power production.

The scope of the Water Resources Investigation Circle extends, division-wise, to the entire Krishna and Bhima basins and all rivers flowing west in Kolaba and Ratnagiri districts; the entire area covered by the Godavari basin within the boundaries of Bombay State and the Penganga and Manjara basins; the Tapi, the Wardha and the Wainganga basins; the river basins in Gujarat area (except the Tapi basin) and all rivers flowing west in Thana District; and the river basins in Saurashtra and Kutch areas.

The creation of this unit follows the decision of the Central Board of Irrigation and Power to set up a suitable machinery for the assessment of irrigation and power potential of different regions of the country to ensure the utilisation of the available resources on a planned and economic basis.

Presumably the investigation by the State Water Resources Investigation Circle should be within the ambit of the Hydro Electric Surveys already conducted and published by the Central Water and Power Commission and will be complementary to the labours of the CW & PC.

New Irrigation Schemes for Madras

Four irrigation schemes, which will benefit an area of about 3.66 lakh acres in the reorganised Madras State, have been included in the Second Five Year Plan. The total cost of the schemes, some of which will be completed in the Third Plan period, is estimated at about Rs. 35.6 crores, of which Rs. 3.48 crores will be spent during the current Plan. Nearly 0.27 lakh acres will come under irrigation during the period.

The New Kattalai High Level Canal, the Pullambady Canal and the Vidur Reservoir are three of the schemes. The fourth one is the multipurpose scheme, which will divert the west-flowing rivers to the east-Parambikulam-Sholayar-Aliyar project estimated to cost Rs. 32 crores, which is expected to benefit 3.20 lakh acres in Coimbatore district and generate 1.24 lakh kW of power. A provision of Rs. 0.70 crores has been made in the Second Plan. The project is under investigation.

Simplified Surge-tank Calculation

The simplified method of surge-tank calculation set out in this paper is based on the assumption that the pressure exerted from the surge tank on the penstock during the initial water-level oscillation (resulting from a variation of the discharge required by the turbines) remains constant. This assumption led to the plotting of two graphs by means of which the volume of water entering or leaving the surge tank at a total or any partial sudden closing or opening of the control valve can be determined. It is further claimed that, when working out estimates in connection with preliminary projects, the two graphs render it possible to obtain at once a first approximation of the volume of the surge tank without resorting to any lengthy trial computation and without having to know accurately in advance the pattern of the surge tank. In addition to these two graphs, two general equations also take into account non-sudden variations of discharge extending over a certain time. (Dr. A. Gardel, Schweizerische Bauzeitung, Vol. 75, No. 31, August 3, 1957 P. 485,5 pp., 6 ff.)

Damping of Surges in Run-of-River Power System

Since its very inception, the harnessing of major rivers to power generation in low-head plants has confronted the operating concerns with the problem of controlling the surges which arise in both head- and tailraces when the discharge through the turbines is suddenly cut down. These surges are particularly dangerous on large navigable rivers such as the Rhone, Rhine, and Danube, where positive shock waves up to 1.5 m. and negative waves 1.2 m. in height have been measured. High negative surges are the more harmful, since they involve the risk of ships being stranded and, at the same time, impair the running of downstream power stations. Following a review of the various methods of surge control applied in plants operating with a headrace or tailrace canal, or built across the river bed with an adjacent spillway block or weir, the author describes the turbine control system evolved by Escher Wyss Ltd., Zurich, and called "stop control gear". This system proceeds from the control methods in use for many years with Kaplan turbines, which prevent the guiding aparatus from fully closing too quickly so that a streaming of the water back into the draught tube is impossible, and the speed of the turbine after the switch-off can be kept within a more favourable range. Practical tests at several major power-stations on the Inn, Danube and Rhine have established that the stop control gear substantially restricts the extent of positive and negative surges and, in addition, bring about a quicker stabilisation of the water level in both headrace and tailrace. (M. Hirt & K. Wiedler, Schweizerische Bauzeitung, Vol. 75, No. 22, June 1, 1957, p. 327, 6 pp., 8 ff., 7 graphs).

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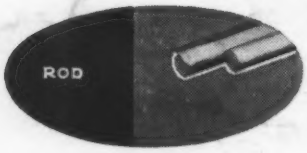

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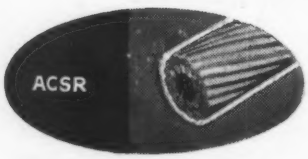

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